(2)

US Army Corps
of Engineers

The Hydrologic
Engineering Center

AD-A235 606

GENERALIZED COMPUTER PROGRAM

HYDUR

Hydropower Analysis Using Streamflow Duration Procedures

Users Manual

September 1982

PROVISIONAL

10 December 1984

Conditions of Use

The following conditions regulate the use of computer programs developed by the Hydrologic Engineering Center (HEC), Corps of Engineers, Department of the Army.

1. The computer programs are furnished by the Government and are accepted and used by the recipient individual or group entity with the express understanding that the United States Government makes no warranties, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information or data contained in the programs, or furnished in connection therewith, and that the United States Government shall be under no liability whatsoever to any individual or group entity by reason of any use made thereof.

2. The programs belong to the United States Government. Therefore, the recipient agrees not to assert any proprietary rights thereto nor to represent the programs to anyone as other than Government programs.

3. The recipient may impose fees on clients only for ordinary charges for applying and modifying these programs.

4. Should the recipient make any modifications to the program(s), the HEC must be informed as to the nature and extent of those modifications. Recipients who modify HEC computer programs assume all responsibility for problems arising from, or related to, those modifications. User support from the HEC to third party recipients will only be provided after the second party demonstrates that program difficulties were not caused by their modifications.

5. This "Condition.' of Use" statement shall be furnished to all third parties that receive copies of HEC programs from the recipient. Third party recipients must be notified that they will not receive routine program updates, correction notices, and other program services from the HEC unless they obtain the program(s) directly from the HEC.

6. All documents and reports conveying information obtai-ed as a result of the use of the program(s) by the recipient, or others, will acknowledge the Hydrologic Engineering Center, Corps of Engineers, Department of the Army, as the origin of the program(s).

Hydropower Analysis

Using Streamflow Duration Procedures

HYDUR
USERS MANUAL

September 1982

THE HYDROLOGIC ENGINEERING CENTER
WATER RESOURCES SUPPORT CENTER
U.S. ARMY CORPS OF ENGINEERS
609 SECOND STREET
DAVIS, CALIFORNIA 95616

(916) 440-2105
FTS 448-2105

ACKNOWLEDGEMENTS

The HYDUR program was developed using streamflow duration techniques developed by Gary M. Franc, James G. Dalton, Dale R. Burnett and Bill S. Eichert for the Corps of Engineers National Hydropower Study in 1979. The procedures for determining project costs were developed by the North Pacific Division.

Jeffrey R. Houghten, under the supervision of Arthur F. Pabst, wrote the computer code for the HYDUR program. Many of the major subroutines were adopted from the National Hydropower study streamflow duration subroutines written by Gary Franc. Edward C. Morris was responsible for designing the program input and for overseeing the testing of the program. Exhibit 2 and subsequent program revisions and enhancements were prepared by Gary Franc.

Hydropower Analysis
Using Streamflow Duration Procedures

HYDUR

USERS MANUAL

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

HYDROPOWER ANALYSIS PROGRAM
USING STREAMFLOW DURATION PROCEDURES

THE HYDROLOGIC ENGINEERING CENTER

1. ORIGIN OF THE PROGRAM

This program was developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers. It is based on techniques used for the Corps National Hydropower Study in 1979 (HEC, 1979c). Up-to-date information and copies of the program can be obtained from the Center upon request.

2. CAPABILITIES OF THE PROGRAM

The HYDUR program has been designed to perform hydroelectic power potential analysis based on flow-duration principles. The basic purpose of the program is to integrate a flow-duration (transformed to capacity-duration) relationship to determine energy. A wide range of options based on the flow duration concept are available for analysis. The options include such important items as considering the number and performance characteristics of generating equipment (efficiency, operating range and overload capacity); availability of water and head; and tailwater effects on generation. The program is thus specifically designed to analyze run-of-river type hydropower projects - that is projects whose storage is not specifically operated to alter the manner of hydropower generation.

The program has two options for providing hydrologic data. A flow duration curve may be directly input or streamflow data may be input and the program derived the flow-duration curve. Options are available to further adjust streamflow through such mechanisms as ratios, losses and diversions.

The program can also produce preliminary estimates of hydroelectric power potential that would commonly require conventional period of record sequential analysis such as is provided by the computer program HEC-5 (HEC 1982). These options were carried over from the analysis procedures used for the national Hydropower Study in which the goal was to perform simple type analysis for virtually all potential projects. These options should be used with due regard for their inherent assumptions thus guarding against the temptation to use the simpler HYDUR analysis when in fact more refined procedures are warranted. Options that fall into this group are those that permit analysis of storage projects (reservoirs operated to conserve runoff for later release), provide for preliminary estimates of construction costs, and provide for national level valuation of power output. A few of the automated cost and benefit items may be overridden with specific input data and more capability to specify site specific costs/ etc., are planned as future improvements to HYDUR.

The power benefit values contained in the program are 1978 regional capacity and energy values developed by the Federal Energy Regulatory Commission (FERC 1978). The cost estimating procedures were developed by the Corps North Pacific Division and were intended for use in the Nationally scoped National Hydropower Study.

The program also has a utility feature that permits automatic sizing of project features. The program can select the optimum capacity of a plant based on maximizing or minimizing any of several criteria. The user is cautioned to be wary of optimum capacities that are determined when using the cost and generalized benefit functions available in the program. Results should be verified for reasonableness and are appropriately considered to be an indicator of possible plant capacity that should be refined by further study based on site and project specific information.

3. COMPUTER REQUIREMENTS

The program available for distribution is written in FORTRAN IV, using 140K words of central memory on a CDC 7600 computer or approximately 1400K bytes. The program uses four scratch units. Unit 1 requires an 89-character record for each input card that is read. Unit 2 requires a record for each data card image read from the alternative file; the record length is dependent on the data format requested by the user. Unit 3 (Unit 8 on Harris version) is used in conjunction with the alternative file. Unit 4 is used as a dump file which contains superfluous output. In addition, to being used as a separate program, HYDUR can be linked as a subroutine to any other program as long as the proper variables are passed through the call statement. The Corps of Engineers version on the Lawrence Berkeley Laboratory (LBL) computer system has additional capabilities that allow it to read flow-duration information directly from GETUSGS data files (HEC, 1979a).

4. METHODS OF COMPUTATION

a. Determination of a Flow-Duration Curve

The flow-duration curve can be calculated from monthly streamflows, daily streamflows, or it can be provided directly. In the first two cases the program counts the number of flow values less than or equal to each of 70 discharge intervals defined by:

$$Q_i = 10^{(i-1)/10} \text{ for } i = 1,70 \qquad \text{(Eq.1)}$$

An additional interval count is made of the flow between zero and 1 cfs. This equation was adopted because it eliminated the need to sort the streamflow data. The logarithmically spaced intervals provide a range of flow intervals that give adequate definition of the flow-duration curve for all size streams.

The number of occurrences greater than or equal to the flow in each interval are determined and divided by the total number of occurrences; thus yielding ordinates that describe the percent of time each interval is exceeded. The ability to develop seasonal streamflow-duration curves and perform subsequent seasonal power analysis is only available in this mode.

When the curve is provided directly, at least 15 to 20 points should be provided to define the curvature because linear interpolation is used to estimate values between the ordinates.

Once the flow-duration curve has been developed, consideration to the type of project and its operation must be evaluated to determine if additional adjustments to the curve are warranted. Analysis of a run-of-river project requires no adjustment to the flow-duration curve since any inflow to the project must be either used for power production or spilled downstream. A storage project, however, is capable of accumulating excess inflow for future use during low-flow periods, thereby converting the inflow-duration curve into a flatter or less peaked outflow-duration curve. If the input flow duration curve or flow record was derived from regulated flows downstream from the project, no further adjustment is needed. If the flows are input, storage should be accounted for. Analysis can be performed externally by hand or machine and values input as above, or if a simplified accounting of the effects of storage is acceptable, the program has an option that will perform the adjustments. The technique developed to perform this storage effect adjustment is discussed in Exhibit 2 entitled, Adjustment of Flow-Duration Curve for Storage Effect. For now, however, it is important to note that once an adjustment is performed, if at all, the remaining procedure applies.

Figure 1 below illustrates the basic analysis procedure. End points are established at 0 and 100% (Maximum and minimum recorded flows) and analysis proceeds.

Power is generated when the flows on the streamflow duration curve are less than QSUB, (Submergence flow), the flows on the curve are greater than QMIN, the minimum flow necessary to drive a turbine and the operating head is above minimum operating head limits.

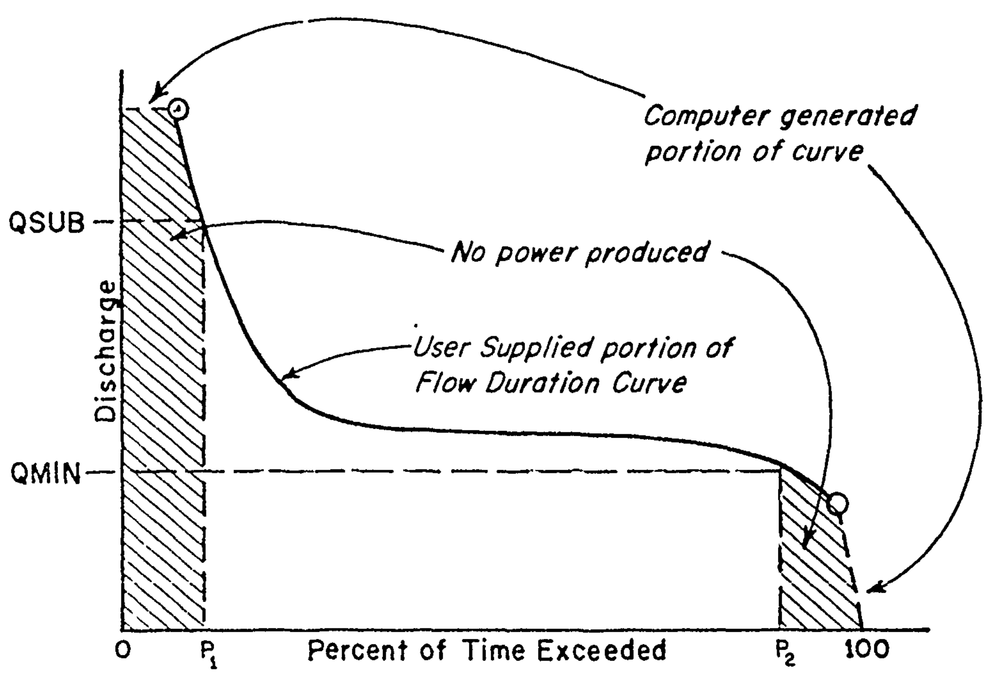


Figure 1. Streamflow Duration Curve

b. Calculation of a Capacity Versus Percent of Time Exceeded Curve

The flow duration curve is transformed to a capacity duration curve as the next step leading to energy calculators.

The portion of the flow-duration curve between points P_1 and P_2 in Figure 1 is broken into 40 evenly spaced percent of time exceeded intervals. Forty-one discharge ordinates are calculated to define the 40 intervals by linearly interpolating between either the computed or the user-supplied streamflow duration coordinates. The capacity duration curve is then constructed from these 41 coordinates as follows:

1) The Power Equation:

$$(CAP)_i = 0.084603 * (HW-TW) * EEF * QA_i \qquad \text{(Eq. 2)}$$

subject to: $QA_i \leq QDES$ (turbine check) (Eq. 3)

$(CAP)_i \leq CAPDES * ØVLOAD$ (generator check) (Eq. 4)

The available discharge to produce power is defined by:

$$QA_i = (Q_i * QFACT) - DIV - QLØSST \quad \text{for}$$
$$QSUB < Q_i < QMIN \text{ or} \qquad \text{(Eq. 5)}$$
$$QA_i = 0 \quad \text{for } Q_i \leq QMIN \text{ or } Q_i \geq QSUB.$$

where:

$(CAP)_i$ = capacity in KW based on the flow QA_i;

Q_i = discharge (cfs) from the flow-duration curve;

QA_i = discharge (cfs) of flow that is available to produce power;

QSUB = Q corresponding to tailwater submergence;

QMIN = Q necessary to drive turbine;

QDES = maximum penstock capacity in cfs;

HW = headwater elevation in feet;

TW = tailwater elevation in feet;

EFF = efficiency ($E_t * E_g * E_h$) expressed as a decimal fraction;

CAPDES = installed capacity of the plant in kilowatts;

ØVLØAD = overload factor of the plant, expressed as a decimal (i.e., 1.15 for a 15% allowable overload);

QFACT = user supplied factor expressed as a decimal used to adjust the streamflow discharges (e.g., drainage area ratio);

DIV = flow diversion in cfs above the powerhouse. (Average evaporation losses can also be included in DIV.)

DIV is subtracted from the streamflow values on the flow-duration curve before performing the power analysis;

QLØSST = diversion of water in cfs around the powerhouse (fish ladder, leakage, etc.) This flow is not used for the power production but effects the headwater and tailwater elevations;

E_t = efficiency of the turbine expressed as a decimal fraction;

E_g = head losses of the overall power configuration expressed as a decimal fraction;

i = one of 41 percent of time exceeded ordinates;

0.084603 = 62.4/737.56, where 62.4 is the weight in pounds of 1 cubic foot of water at 50°F and 737.56 is the conversion factor from 1 kilowatt to 737.56 ft-lbs/sec.

2) Additional Hydrologic Parameters

The amount of spillage $QS_i = (Q_i*QFACT) - DIV - QLØSST - QA_i$ (Eq. 6)

subject to $QS_i \geq 0$

Whenever QA_i is less than or equal to QDES and is also within the flow limits defined by QSUB and QMIN, then QS_i will be zero.

The HW term can be specified as a function of total reservoir releases QR_i, which is expressed as:

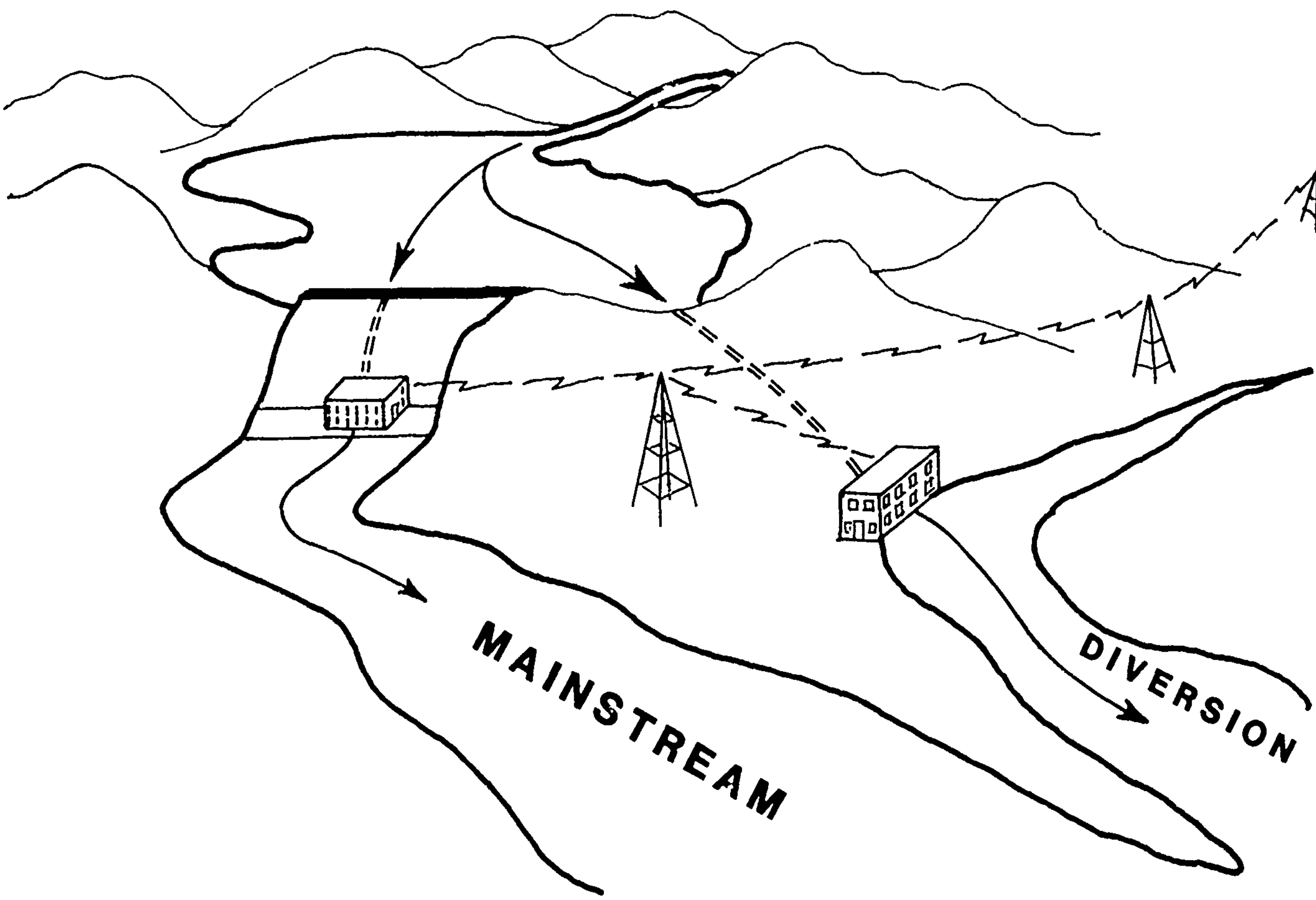
$$QR_i = QA_i + QS_i \quad \text{(Eq. 7)}$$

The efficiency EFF can be specified as a function of QA_i.
The TW term can be specified as a function of the tailwater flow QT_i. QT_i is defined in one of two ways depending upon user selection:

$$QT_i = QA_i/UAPD + QS_i \quad \text{or} \quad QT_i = QA_i/UAPF \quad \text{(Eq. 8)}$$

Where UAPF represents a factor between 0 and 1.0 which is used to adjust the daily mean flow available QA_i to a value which represents the actual flow passing through the penstocks during times of power operation only.

The spillage QS_i is added to the tailwater flow whenever this flow will effect power operations. In configurations where the powerhouse is remotely situated from the inpoundment and spillway structure, the spill effect should not be included (See Figure 2).



TAILWATER WITH SPILL EFFECT

TAILWATER WITHOUT SPILL EFFECT

Figure 2. Schematic of Spill Effect

3) The program makes a final adjustment of the capacity duration curve to guarantee that it monotonically decreases. A capacity curve that does not so decrease is not logical. The adjustment is a simple reordering of values in decreasing order.

c. Calculation of Average Energy

Average energy is calculated by integrating the area under the capacity verses percent of time exceeded relationship derived in the previous steps. Figure 3 is a schematic of the curve.

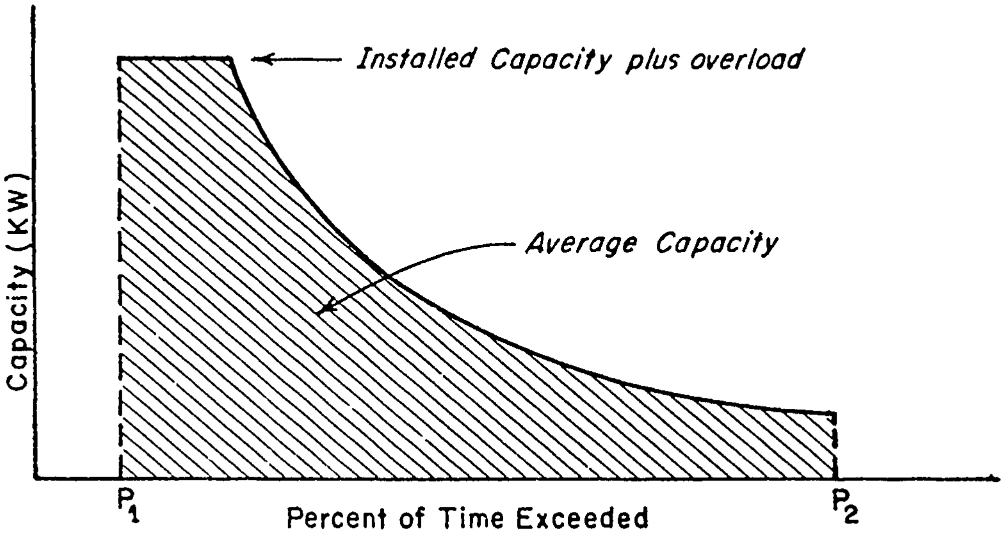


Figure 3. Capacity versus Percent of Time Exceeded Curve

$$AE = F(8.76) * \int_{P_1}^{P_2} (CAP)_i \ dp \approx F(8.76) * \sum_{i=P_1}^{P_2} \frac{Si}{3} * (CAP)_i * \Delta P \qquad \text{(Eq. 9)}$$

where: AE = average energy in megawatt-hours (MWH);

$(CAP)_i$ = capacity in KW at the ith percent of time exceeded ordinate;

$(dp, \Delta P)$ = percent of time exceeded interval;

P_1 = lower limit of integration which is equal to the percent of time exceeded ordinate associated with QSUB;

P_2 = upper limit of integration which is equal to the percent of time exceeded ordinate associated with QMIN;

S_i = Simpson's integration constant, where:

S_i = 1 for i = 1, 41 (first and last ordinates);

S_i = 4 for i = 2,4,6 . . . 40 (even ordinates);

S_i = 2 for i = 3,5,7 . . . 39 (odd ordinates);

8.76 = 8760 hours/1000 KW, a constant that converts KW to the MWH generated in a year;

F = length of season expressed in years. $(0.083 \leq F \leq 1.0)$ For annual analyses, the value of F is 1.0. For seasonal analyses, the values of F must be greater than or equal to 1/12 and less than 1.0.

d. Calculation of the Plant Factor

The plant factor is defined as the ratio of the average load on the plant for a given time period to the aggregate rating of all the generating equipment installed in the plant.

$$PF = AE / (CAPDES * 8.76 * F) \qquad \text{(Eq. 10)}$$

where: PF = Plant Factor; (for a given time period);

AE = Average energy in MWH;

CAPDES = Installed plant capacity in KW. 8.76 is a conversion factor based on (1,000 KW/MW) / (8760 hours/year);

F = 1.0 for annual power analyses.

e. Determination of Dependable Capacity and Annual Firm Energy

The HYDUR program includes routines for determing approximate estimates of dependable capacity and annual firm energy. The conventional approach for usch estimates requires sequential analysis of power production coupled with the system load relationship. Approximate methods based on flow-duration principles of analysis have been developed and included in HYDUR.

IACWR defines dependable capacity as the "load-carrying ability of a station or system under adverse conditions for the time interval and period specified when related to the characteristics of the load to be supplied." Annual firm energy is defined (IACWR, 1965) as: "electric energy which is intended to have assured availability to the customer to meet all or any agreed upon portion of his load requirements."

The flow-duration curve constructed from the reservoir inflows does not account for the reduction of the inflow variability that occurs when a reservoir is constructed. It is quite possible that while reservoir inflows may be zero for several months during the critical period, carry-over storage may maintain dependable discharges from the project. Therefore, the minimum power releases from a project are generally considerably higher than the minimum reservoir inflows. The magnitude of this effect will depend upon the variability of the inflow regime, the storage capacity of the reservoir, the release schedule of the project, and the length of the drought period. Thus the flow duration curve to be used for power analysis must account for storage effects. If a storage adjusted curve is not input directly, an approximately estimate of storage effects can be considered by activating the HYDUR storage adjustment routine (see Exhibit 2).

The computer program has capabilities to handle a user-supplied dependable capacity (DCAP) or it can calculate dependable capacity from a head and minimum discharge (DC). The program calculates the dependable capacity from the discharge on the flow-duration curve associated with a user-supplied percent of time exceeded called SRP, the streamflow reliability percentage. The program contains a default value of 85% for SRP, an approximation for a 15% forced outage percentage commonly used for fossil fueled generating plants which are often the most likely alternative to hydropower plants. The net head is based on the user-supplied discharge versus headwater and tailwater relationships.

The firm energy, FE expressed in megawatt-hours is calculated using Equation 9 with the maximum value of term $(CAP)_i$ constrained to the dependable capacity.

$$(CAP)_i \leq DC \qquad \text{(Eq. 11)}$$

f. Interruptible Capacity and Energy

Interruptible capacity, IC, as used herein, is defined as the capacity (KW) that the supplier can curtail at his discretion.

$$IC = CAPDES - DC \qquad \text{(Eq. 12)}$$

Secondary energy, SE, is simply the energy (MWH) difference between the average energy and the firm energy.

$$SE = AE - FE \qquad \text{(Eq. 13)}$$

g. Potential Energy Losses

The production of average energy can be limited by the installed capacity of the plant, by the discharge capacity of the penstock, or by both. The program internally computes the maximum potential energy by using the power equation (Eq. 2) without considering the penstock constraint (Eq. 3) or the installed capacity times the overload constraint (Eq. 4). The average energy based on the power equation (Eq. 2) with only the installed capacity times the overload constraint (Eq. 4) is calculated and subtracted from the maximum potential average energy yielding, AELC, the average energy lost due to insufficient installed capacity. Similarly, the average energy calculated with only the penstock discharge capacity as a constraint (Eq. 3) is subtracted from the maximum potential average energy yielding, AELQ, the average energy lost due to insufficient penstock capacity. The constraints on the capacities used in the calculation of AELC and AELQ are shown below in Figure 4 for two possible cases.

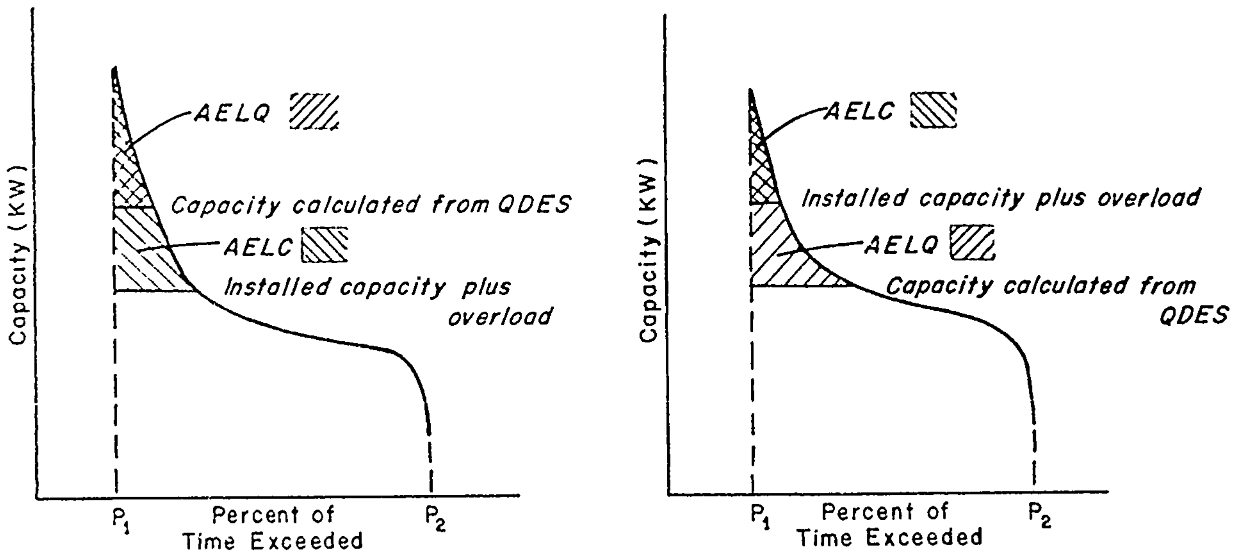


Figure 4. Potential Energy Losses

h. Calculation of Power Benefits

HYDUR can compute the value of power generated (power benefits) from user supplied values (with several variations) or from regional values stored in the program. Capacity and energy benefits are specified as functions of annual plant factor (the values may be adjusted by ratios). The annual capacity benefit is computed as the product of the capacity times the appropriately interpolated (based on annual plant factors) capacity value. The annual energy benefit is similarly calculated. The total annual benefit is the sum of the two.

Power benefits computed from regional values stored in the program should be considered very approximate-suitable for very general preliminary studies. The benefit values are based on regional studies performed by FERC based on 1978 data. Benefit computations consider region dependable and interruplible capacity and firm and secondary energy.

The dependable capacity benefit in dollars per year is found by multiplying the dependable capacity by a regional capacity benefit factor, CB, which is a function of the plant factor (see Table 1a). The regions applicable are defined in Figure 5. The units of CB are dollars per kilowatt-year.

The interruptible capacity benefit, in dollars per year is computed by multiplying interruptible capacity times the product of the capacity benefit and capacity benefit reduction factor.

The energy benefit in dollars per year, is calculated by multiplying the firm energy by the regional firm energy benefit value (see Table 1b). The secondary energy benefit is computed similar to the interruptible capacity benefit.

The total benefit in dollars per year is the sum of the four components thus computed.

i. Calculation of Project Costs

HYDUR can consider cost in computations from user supplied values or from general relationships stored in the program. User supplied costs are possible only for single capacity analyses - thus may not be used in automatic sizing computations. Program supplied cost functions are general and are therefore required for use if optimization analyses considering costs are to be performed.

Program supplied costs are taken directly from a cost manual developed by the Corps North Pacific Division (NPD(1979)). The procedures were developed for nation-wide reconnaissance level cost estimates of single-purpose power projects. The cost relationships were based on empirical curves associating project physical parameters to site component costs. All costs were in July 1978 dollars. Costs generated from the relationships should be considered very preliminary and verified for reasonableness subsequent to computer runs.

Cost curves are included for the powerplant, embankment, spillway, intake and outlet structures, waterway, and the reservoir acquistion and clearing costs. Additional special cost items may be included. Investment costs include construction costs plus contingency factor, engineering overhead, and interest during construction. A geographic adjustment is possible. Annual project costs are determined by amortizing these costs and adding the annual operation, maintenance, and interim replacement costs. A complete description of the cost estimates procedures in contained in the NPD (1979) document and summarized in Figure 6.

ELECTRIC POWER SUPPLY AREAS IN THE UNITED STATES

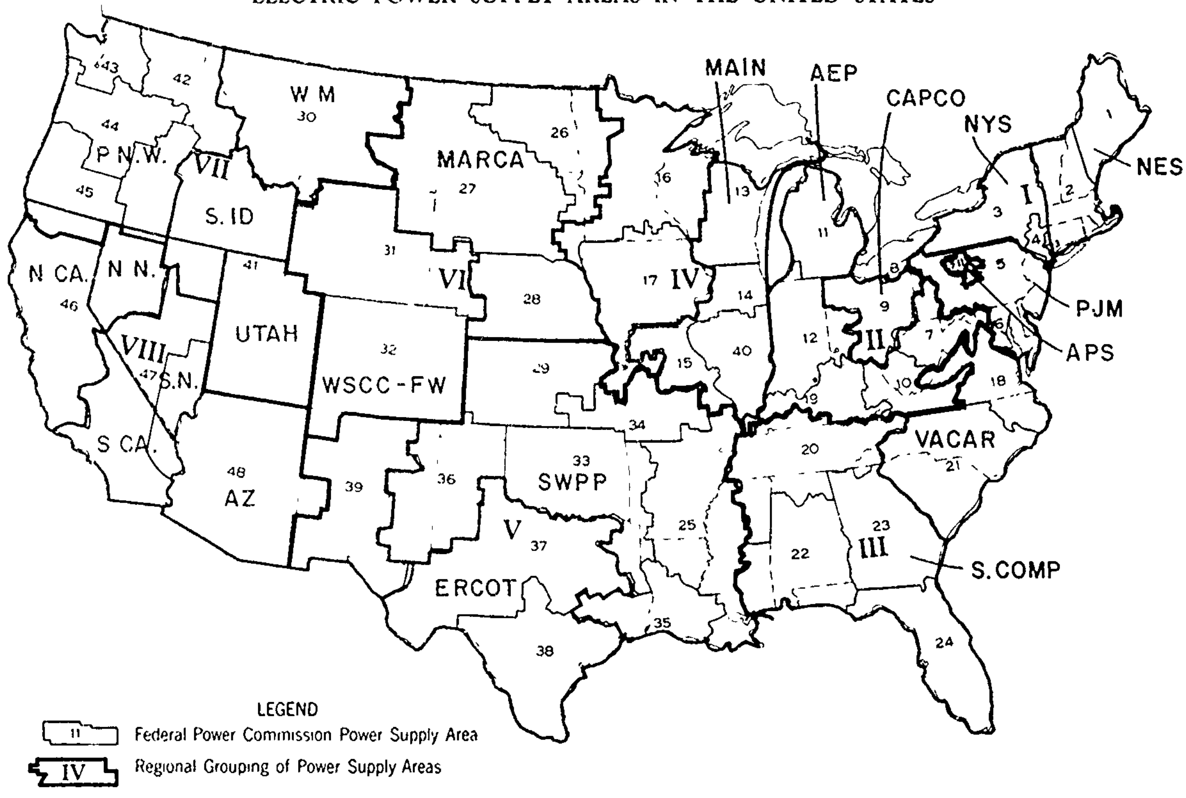


Figure 5. FERC Regions for Capacity and Energy Benefits (from Hydroelectric Power Evaluation, Federal Power Commission, Washington, D.C., March 1968

COST ESTIMATE FORM
($1,000,000)
July 1978 Price Level

	Major Cost Items	First Cost	Total Cost
(1)	Powerplant	$	
(2)	Embankment (Dams, Dikes)		
(3)	Spillway		
(4)	Intake & Outlet		
(5)	Waterway (Canal, Channel, Conduit)		
(6)	Reservoir		
	Investment Cost Computations		
(7)	Total First Cost Subtotal A = Σ((1) through (6))	$	
(8)	(7) x Geographic Factor (_.__)	$	
(9)	Land Costs*		
(10)	Subtotal B = ((8) + (9)) x Contingency (1.__)		$
(11)	Special Cost Items**		
(12)	Total Construction Cost Subtotal C = (10) + (11)		$
(13)	Engineering and Overhead Costs ((12) x K_{engr} (__._%)		
(14)	Total Project Cost Subtotal D = (12) + (13)		$
(15)	Interest During Construction ((14) x IDC (0.____))		
(16)	Total Investment Cost ((14) + (15))		$
	Annual Cost Computations		
(17)	Amortized Cost (Amortization Factor (0._____) x (16))		$
(18)	Operation and Maintenance Costs		
(19)	Replacement Costs Geographic Factor (_.__ x (0.0125) x (1) x Contingency (1.__)		
(20)	Total Annual Cost = ((17) + (18) + (19))		$

* Geographic Factor not applied as Land requires no geographic adjustment for acquisition.

** Geographic and Land Factors and Contingencies not applied as special costs are user supplied, include concern for local cost differences, and reflect level of study.

Figure 6

Table 1a. Regional Energy Benefit Values (FERC, 1978)

FERC Region Code	Region	Energy Benefit as function of APF ($/MWH) APF: 0	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
1	VACAR	45.3	45.3	45.3	35.7	35.7	11.0	11.0	4.8	4.8	4.8	4.8
2	Southern Companies (S. COMP)	45.0	45.0	45.0	35.7	35.7	9.1	9.1	4.8	4.8	4.8	4.3
3	ECAR	38.2	38.2	38.8	23.5	23.1	12.7	12.6	12.5	12.4	12.4	12.3
4	MAIN	43.9	43.9	41.6	25.4	23.5	12.9	12.4	12.0	11.8	11.6	11.4
5	MARCA	40.3	40.3	37.2	24.1	22.6	10.1	10.0	9.9	9.8	9.7	9.7
6	WSCC-FW	33.5	33.5	27.4	24.1	23.6	5.8	6.7	7.3	7.8	8.2	8.5
7	SWPP	35.2	35.2	34.9	23.3	22.1	12.0	11.9	11.9	11.9	11.8	11.8
8	ERCOT	29.8	29.8	23.8	22.6	21.1	9.4	9.6	9.7	9.8	9.9	9.9
9	New England (NES)	35.5	35.5	30.5	28.9	27.1	1.0	4.0	6.0	7.6	8.8	9.8
10	New York (NYS)	39.2	39.2	39.1	29.2	26.9	10.5	11.8	12.8	13.5	14.1	14.5
11	PJM	38.6	38.6	36.2	29.8	28.1	11.3	11.5	11.6	11.7	11.8	11.9
12	CAPCO	37.6	37.6	33.8	29.8	26.7	2.8	4.5	5.6	6.5	7.2	7.8
13	AEP	33.2	33.2	22.9	29.8	25.1	9.4	9.5	9.6	9.7	9.7	9.7
14	APS	45.0	45.0	49.1	31.1	23.7	9.4	9.8	10.1	10.3	10.4	10.5
15	Northern California (N.CA.)	34.4	34.4	35.[illegible]	21.2	21.6	11.8	13.0	13.8	14.4	14.9	15.3
16	Southern California (S.CA.)	33.8	33.8	33.6	21.0	21.4	10.0	11.0	11.6	12.1	12.5	12.8
17	Pacific Northwest (P.N.W.)	31.9	31.9	26.7	21.1	21.2	14.1	13.5	13.1	12.7	12.5	12.3
18	Arizona (AZ)	34.6	34.6	34.6	21.8	22.4	15.2	14.7	14.4	14.2	14.0	13.9
19	Southern Idaho (S.ID.)	39.0	39.0	43.3	22.4	22.4	9.7	10.0	10.2	10.4	10.5	10.6
20	Western Montana (W.M.)	39.4	39.4	45.2	22.0	22.1	3.4	3.4	3.4	3.4	3.4	3.4
21	Northern Nevada (N.N.)	38.5	38.5	44.8	21.4	21.6	10.7	11.8	12.6	13.1	13.6	13.9
22	Southern Nevada (S.N.)	36.1	36.1	39.5	21.3	21.9	9.3	9.1	9.0	8.8	8.7	8.7
23	Utah	34.3	34.3	34.0	20.0	18.5	7.7	7.8	7.8	7.8	7.9	7.9
24	Island of Oahu, Hawaii	35.5	35.5	32.9	24.2	25.7	20.1	21.2	22.0	22.7	23.1	23.5
25	Island of Hawaii, Hawaii	7.9	7.9	21.4	25.9	28.2	25.7	26.7	27.5	28.0	28.5	28.8
26	Island of Kauai, Hawaii	7.6	7.6	21.3	25.9	28.1	25.7	26.7	27.5	28.1	28.5	28.8
27	Island of Maui, Hawaii	4.4	4.4	20.1	25.4	28.0	25.6	26.8	27.6	28.2	28.7	29.1
28	Island of Molakai, Hawaii	22.8	22.8	32.0	35.1	36.6	37.5	38.1	38.6	38.9	39.1	39.3
29	Anchorage, Alaska	20.6	20.6	20.3	8.7	11.4	10.1	10.9	11.5	12.0	12.4	12.6
30	Fairbanks, Alaska	27.0	27.0	29.1	29.8	30.2	8.7	8.9	9.0	9.1	9.2	9.3
31	Valdez, Alaska	38.6	38.6	38.6	38.6	38.6	38.6	38.6	38.6	38.6	38.6	38.6
32	Ketchikan, Alaska	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6	32.6

Table 1b. Regional Capacity Benefit Values (FERC, 1978)

FERC Region Code	Region	Capacity Benefit as function of APF ($/KW) APF: 0	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
1	VACAR	25.1	25.5	25.9	40.9	31.0	120.1	121.8	179.0	184.3	189.6	194.6
2	Southern Companies (S.COMP)	30.1	21.2	12.3	45.0	43.1	109.5	111.8	170.7	175.5	180.4	185.3
3	ECAR	31.9	32.8	32.8	66.1	66.1	135.2	135.2	135.2	135.2	135.2	135.2
4	MAIN	37.2	33.2	33.2	67.1	67.1	134.9	134.9	134.9	134.9	134.9	134.9
5	MARCA	36.9	31.5	31.5	63.5	63.5	135.5	135.5	135.5	135.5	135.5	135.5
6	WSCC-FW	40.8	30.1	30.1	68.1	68.1	130.8	130.8	130.8	130.8	130.8	130.8
7	SWPP	30.8	30.4	30.4	68.9	68.9	125.1	125.1	125.1	125.1	125.1	125.1
8	ERCOT	39.8	29.3	29.3	65.9	65.9	119.0	119.0	119.0	119.0	119.0	119.0
9	New England (NES)	39.3	30.5	30.5	70.0	70.0	188.1	188.1	188.1	188.1	188.1	188.1
10	New York (NYS)	33.3	33.0	33.0	75.5	75.5	183.7	183.7	183.7	183.7	183.7	183.7
11	PJM	32.5	28.2	28.2	64.9	64.9	136.0	136.0	136.0	136.0	136.0	136.0
12	CAPCO	36.0	29.3	29.3	67.5	67.5	180.1	180.1	180.1	180.1	180.1	180.1
13	AEP	45.4	27.3	27.3	62.5	62.5	110.0	110.0	110.0	110.0	110.0	110.0
14	APS	20.4	27.5	27.5	62.5	62.5	139.4	139.4	139.4	139.4	139.4	139.4
15	Northern California (N.CA.)	36.1	37.6	37.6	69.7	69.7	156.5	156.5	156.5	156.5	156.5	156.5
16	Southern California (S.CA.)	50.0	49.6	49.6	80.4	80.4	164.8	164.8	164.8	164.8	164.8	164.8
17	Pacific Northwest (P.N.W.)	30.3	24.7	24.7	53.6	53.6	121.0	121.0	121.0	121.0	121.0	121.0
18	Arizona (AZ)	44.2	44.3	44.3	86.8	86.8	224.0	224.0	224.0	224.0	224.0	224.0
19	Southern Idaho (S.ID.)	21.6	35.4	35.4	71.0	71.0	160.1	160.1	160.0	160.1	160.0	160.1
20	Western Montana (W.M.)	27.1	37.2	37.2	74.3	74.3	161.5	161.5	161.5	161.5	161.5	161.5
21	Northern Nevada (N.N.)	24.1	35.0	35.0	70.1	70.1	197.4	197.4	197.4	197.4	197.4	197.4
22	Southern Nevada (S.N.)	30.5	36.5	36.5	72.6	72.6	164.4	164.4	164.4	164.4	164.4	164.4
23	Utah	36.8	36.2	36.2	72.3	72.3	162.2	162.2	162.2	162.2	162.2	162.2
24	Island of Oahu, Hawaii	49.5	45.0	45.0	75.4	75.4	120.6	120.6	120.6	120.6	120.6	120.6
25	Island of Hawaii, Hawaii	78.7	102.3	102.3	102.3	102.3	169.4	169.4	169.4	169.4	169.4	169.4
26	Island of Kauai, Hawaii	78.4	102.3	102.3	102.3	102.3	169.4	169.4	169.4	169.4	169.4	169.4
27	Island of Maui, Hawaii	55.1	82.7	82.7	82.7	82.7	171.1	171.1	171.1	171.1	171.1	171.1
28	Island of Molakai, HI	103.6	119.7	119.7	119.7	119.7	119.7	119.7	119.7	119.7	119.7	119.7
29	Anchorage, Alaska	30.5	30.4	30.4	48.4	48.4	124.5	124.5	124.5	124.5	124.5	124.5
30	Fairbanks, Alaska	35.7	37.1	37.1	37.1	37.1	149.5	149.5	149.5	149.5	149.5	149.5
31	Valdez, Alaska	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0	109.0
32	Ketchikan, Alaska	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5	49.5

The total annual cost developed from the NPD cost procedures is used to calculate the installed capacity cost in dollars per kilowatt-year.

Likewise the average energy cost in dollars per megawatt-hour is computed by dividing the total annual cost by the annual energy.

Finally net benefits are computed as total annual benefits minus total annual cost and the benefit-cost ratio determined as the total annual benefit divided by the total annual cost.

5. METHODS OF OPERATION

The HYDUR program may be operated in two basic modes. In the first mode the user supplies the installed capacity of the plant, and the program computes the average annual energy, and if so specified, costs and benefits as well. In the second mode, the computer program selects the installed capacity that optimizes a user specified objective function.

a. User Supplied Capacity

In order to invoke this option the user simply provides the capacity value CAPDES.

b. Optimization of Capacity

When CAPDES is not specified, ten flows that correspond to default intervals of 1, 5. 10, 20, 40, 60, 90, 95, 99 percent of time exceeded on the flow-duration curve are used to calculate an array of capacity values and their corresponding power parameters. An optimization scheme determines the installed capacity based upon a user defined objective function.

When installed capacity currently exists at the project all calculated power parameters are incremental values (i.e., total-existing).

c. Data Entry Using the Alternative File

The user designates whether the streamflow or streamflow duration data sets are to be read from data cards or from an alternative file. The alternative file is an existing data file that is created before the HYDUR program is executed. (See Exhibit 6.)

d. Use of the HYDUR Program as a Subroutine

The HYDUR program can be used as a separate subroutine to another program. The requirements for doing so are outlined in Exhibit 5.

e. Overview of Program Options and Capability

1) Calculates an annual or seasonal streamflow duration curve (SD card) from streamflow data.

2) Calculates a capacity-duration curve and average energy for any streamflow duration curve.

-the installed capacity is either user supplied or internally calculated by optimizing a user supplied criterion.

-the net head is user supplied or both the headwater and tailwater can be a function of the discharge.

-the user supplies the minimum Q to turn the turbine, the maximum Q that submerges the powerhouse, streamflow diversions, and any leakage or seepage through or around the dam.

6. INPUT

Input data preparation is described in detail in Exhibit 7. Flow data may also be entered using an alternative file as described in Exhibit 6. Example problems illustrating input preparation are shown in Exhibit 3.

The Standard Input Format used in the program is ten 8-column fields per card. Column 1 and 2 are used for card identification. An integer or alpha numeric entry must be right-justified in its field. A non-integer entry must be right-justified if a decimal point is not provided. The sequence of card input is generally insignificant (except for reading of flow records).

A free format option is available that allows the user to separate values on an input card with blanks or commas rather than using the standard 10 fields of 8 columns each. This option will facilitate input submitted through time sharing terminals.

The following cards are required to perform a HYDUR ananlysis:

1. At least one title card (T1 through T4).

2. FL or FD: Streamflow or Streamflow Duration data cards. These cards indicate the type of data to be input and its format.

3. PD: Power design data is provided on this card. (Installed capacity, design head, efficiency, etc.)

4. EJ: End of Job Card.

7 OUTPUT

Exhibit 4 contains a description of the output data and Exhibit 3 illustrates output for the example problems.

In general, output from the program is controlled through user input of the PS card. Detailed display of internal computer computations may be activated by proper coding of the tenth field of this card. (See Exhibit 7.)

8. DEFINITION OF TERMS

Exhibit 7 describes the variables read as input to the program, while Exhibit 1 defines the important variables calculated within the program.

Table 2

Calculated Power Information

Item No.	Mathematical Expression	Variable Name	Description
1	Item 1	CAPDES	Installed Capacity (KW)
2	Item 2	AAE	Average Annual Energy (MWH)
3	Item 2/(8.76*Item 1)	APF	Average Plant Factor
4	Item 4	DC	Dependable Capacity (KW)
5	Item 5	AFE	Annual Firm Energy (MWH)
6	Item 1 - Item 4	IC	Interruptible Capacity (KW)
7	Item 2 - Item 5	ASE	Annual Secondary Energy (MWH)
8	Item 8	AEFE	Annual Equivalent Firm Energy (MWH)
9-14	(reserved for future use)		
15	Item 15	AELQ	Average Annual Energy Lost Due to Insufficient Penstock Capacity (MWH)
16	Item 16	AELC	Average Annual Energy Lost Due to Insufficient Generating Capacity (MWH)
17	Item 17	CB	Dependable Capacity Benefit ($/KW-YR)
18	CBR * Item 17	ICB	Interruptible Capacity Benefit ($/KW-YR)
19	Item 19	EB	Average Annual Energy Benefit ($/MWH)
20	(Item 4 * Item 17) + (Item 6 * Item 18)	ACB	Annual Capacity Benefit ($/YR)
21	(Item 5 * Item 19) + Item 7 * F (19))	AEB	Annual Energy Benefit ($/YR)

Table 2 (Continued)

Calculated Power Information

Item No.	Mathematical Expression	Variable Name	Description
22	Item 20 + Item 21	TAB	Total Annual Benefit ($/YR)
23	Item 25/Item 1	ICC	Installed Capacity Cost ($/KW-YR)
24	Item 25/Item 2	AAEC	Average Annual Energy Cost ($/MWH)
25	Item 25	TAC	Total Annual Cost ($/YR)
26	Item 22 - Item 25	TANB	Total Annual Net Benefit ($/YR)
27	Item 22/Item 25	BCR	Benefit-to-Cost Ratio
28-30	(reserved for future use)		

9. REFERENCES

a. Federal Energy Regulatory Commission, letter to the Institute for Water Resources, "Preliminary Generalized Power Values for the National Hydropower Study," 23 June 1978.

b. Hydrologic Engineering Center, U.S. Army Corps of Engineers, "GETUSGS Users Manual," March 1979a.

c. Hydrologic Engineering Center, U.S. Army Corps of Engineers, "Users Manual, Hydropower Cost Estimating Program," September 1979b.

d. Hydrologic Engineering Center, U.S. Army Corps of Engineers, "National Hydropower Study Data Base Description, Form 1 Data Base," September 1979c.

e. Hydrologic Engineering Center, U.S. Army Corps of Engineers, "HEC-5, Simulation of Flood Control Conservation Systems: (Users Manual), April 1982.

f. Inter-Agency Committee on Water Resources, "Glossary of Important Power and Rate Terms, Abbreviations, and Units of Measurement," 1965.

g. North Pacific Division, U.S. Army Corps of Engineers, "Hydropower Cost Estimating Manual," May 1979.

Exhibit 1

DEFINITIONS OF SELECTED VARIABLES USED IN THE HYDUR PROGRAM

1. Variables contained in common block POWIN.

AAEST	-	user supplied average annual energy estimate in MWH. This value will override any machine-determined estimate. (See PB card in Exhibit 7.)
AMOR (100)1/	-	Amortization period in years used by the program in determining total annual costs. (See CF card in Exhibit 7.)
AVGQ	-	machined-determined estimate of average annual flow in cfs or cms. This estimate is based on integrating the flow-duration curve while accounting for any losses.
CALCS (0)	-	indication code dealing with print suppression of HYDUR output. A code of zero suppresses no output. A code of seven suppresses output of all calculated results. (See PS card description in Exhibit 7.)
CAPDES (0)	-	user-supplied installed capacity in KW. If not defined the program will select a capacity value based on some objective function. (See PD card in Exhibit 7.)
CAPYMN (0)	-	user-supplied minimum installed capacity (KW) to interrogate when operating the program in the optimization mode. (See SD card in Exhibit 7.)
CAPYMX (0)	-	user-supplied maximum installed capacity (KW) to interrogate when operating program in the optimization mode. (See SD card in Exhibit 7.)
CB	-	array used to store user-supplied capacity benefits. (See CB card in Exhibit 7.)
CBFLAG	-	logical variable indicating whether the program default (true) or the user-supplied (false) capacity benefits are used.
CBR (0.5)	-	capacity benefit reduction factor expressed as a decimal fraction. This value is multiplied by the capacity benefit factor to determine the value of interruptible capacity. (See PB card in Exhibit 7.)

1/ Number in parenthesis is the default value assigned to the variable.

CEFS (0) - print suppression code dealing with cost estimate output. A zero implies no print suppression while a three suppresses all cost estimate output. (See PS card in Exhibit 7.)

CEMB (0) - user-supplied estimate of embankment costs in $1,000. (See C2 card in Exhibit 7.)

CIO - (0) user-supplied estimate of inlet and outlet costs in $1,000. (See C2 card in Exhibit 7.)

CLA (0) - user-supplied estimate of land acquisition cost in $1,000. (See C2 card in Exhibit 7.)

CMIS (0) - user-supplied estimate of additional miscellaneous costs in $1,000 that are not considered in the program's cost routines. (See C2 card of Exhibit 7.)

CONT (0.25) - user-supplied contingency factor to be used in determining total annual costs. (See CF card in Exhibit 7.)

COSTR (1.0) - adjustment factor, expressed as a decimal, which is applied to the total annual cost calculated by the cost routines. (See C2 card in Exhibit 7.)

CPWH (0) - user-supplied estimate of powerhouse costs in $1,000. (See C2 card in Exhibit 7.)

CRATIO (1.0) - user-defined adjustment factor, expressed as a decimal fraction, which is multiplied to the resulting computed total annual capacity benefit. (See PB card in Exhibit 7.)

CRC (0) - user-supplied estimated of reservoir clearing costs in $1,000. (See C2 card in Exhibit 7.)

CSPW (0) - user-supplied estimate of spillway costs in $1,000. (See C2 card in Exhibit 7.)

CWWY (0) - user-supplied waterway cost in $1,000. (See C2 card in Exhibit 7.)

DCAP (0) - user-supplied dependable capacity in KW, which will override any program estimate. (See PB card in Exhibit 7.)

DIST (0) - user-supplied dam length in feet or meters required to estimate embankment costs using the program's cost routines. (See C1 card in Exhibit 7.)

DIV (0)	-	diversion in cfs or cms. Water diverted above the power installation that is not available to produce power. (See PQ card in Exhibit 7.)
EB (0)	-	array used to store energy benefits in dollars per MWH. (See EB card in Exhibit 7.)
EBFLAG	-	logical variable indicating whether the program default (true) or the user-supplied (false) energy benefits are used.
ECAP (0)	-	total amount of existing installed capacity (KW) at the project. (See C1 card in Exhibit 7.)
ECHOS (0)	-	print suppression code dealing with input summary printed by the program. A zero supresses no output while a one suppresses all input summary. (See PS card in Exhibit 7.)
EFF (0.86)	-	combined efficiency of the turbine and generator units expressed as a decimal fraction. EFF will be overridden if TE cards are input. (See PD card in Exhibit 7.)
ERATIO (1.0)	-	user-supplied adjustment factor, expressed as a decimal fraction, which is multiplied to the resulting computed total annual energy benefit. (See PB card in Exhibit 7.)
FLOWLO (0)	-	indicator which specifies whether or not a valid streamflow value has been input. (See FL card in Exhibit 7.)
HEAD (0)	-	gross operating power head in feet or meters. (See PD card in Exhibit 7.)
HEIGHT (0)	-	user-supplied dam height in feet or meters required to estimate embankment costs using the programs's cost routine. (See C1 card in Exhibit 7.)
HMAX (100000)	-	user-supplied power head in feet or meters which is the upper operating limit for the installed unit(s). (See PQ card in Exhibit 7.)
HMIN (0)	-	user-supplied power head in feet or meters which is the lowest operating limit for the installed units(s). (See PQ card in Exhibit 7.)
ICOMB (0)	-	combination code used in the defining of an objective function for selecting an optimal capacity size. (See OC card in Exhibit 7.)
INTBIAS	-	initial pointer to the streamflow values used in developing seasonal flow-duration curves. (See SD card in Exhibit 7.)

IPOWANL	-	flag which indicates whether a complete power analysis or only a flow-duration curve be constructed. (See FL card in Exhibit 7.)
IPRNTS (0)	-	print suppression code used in seasonal power analysis runs only. (See PS card in Exhibit 7.)
IPROJ (0)	-	code used to delete consideration of certain primary costs components calculated by the cost routine. (See C1 card in Exhibit 7.)
IREG (0)	-	region code to select the proper regional benefit curves in the program. (See PB card in Exhibit 7.)
ISEASN (1)	-	contains the current season number (1-12) during seasonal power analyses runs only.
IVAR1 (26)	-	item description code which corresponds to the first data item used in defining the objective function. (See OC card in Exhibit 7.)
IVAR2 (0)	-	item description code which corresponds to the second data item used in defining the objective function. (See OC card in Exhibit 7.)
JSTATE (0)	-	state code used by the cost routine to determine the proper geographical adjustment to apply to the calculated primary cost components. (See C2 card in Exhibit 7.)
KS (1)	-	valley slope code used in determining embankment costs. (See C1 card in Exhibit 7.)
LENREC (80)	-	record length of the alternative file. (See FL Card in Exhibit 7.)
LSTRD	-	temporarily not used.
NCLUDE (ALL)	-	number of consecutive flow values used in developing a flow-duration curve. (See SD card in Exhibit 7.)
NJOB	-	current job number of the entire computer run.
NINYR	-	number of flow values comprising a year. (See SD card in Exhibit 7.)
NOP	-	number of points comprising the OP array.

NPQ (70) - an integer variable describing the number of coordinates used to define the streamflow duration curve.

NSEASKP (0) - number of flow values to skip between seasonal power runs. (See SD card in Exhibit 7.)

NSEASN (1) - number of seasons to perform in power analyses. (See SD card in Exhibit 7.)

NT - number of points comprising the tailwater-discharge relationship. (See TW card in Exhibit 7.)

OP - array of percent exceedance values used in the capacity selection mode of the program. (See OP card in Exhibit 7.)

OPER (L) - operational mode indicator which is used in the determination of annual operation costs. (See C1 card in Exhibit 7.)

OPERND (MAX) - indicator which determines if the objective function used in selecting capacity should be maximized or minimized. (See OC card in Exhibit 7.)

OVLOAD (1.15) - installed capacity overload factor. (See PD card in Exhibit 7.)

PE - array used to store percent exceedence of the streamflow-duration curve.

PEAKF (1) - peaking factor used to analyze the marketability of a project. (See PD card in Exhibit 7.)

PLOTS (0) - print suppression code dealing with plotted output of the program. (See PS card in Exhibit 7.)

PSR (0) - power storage ratio used in analyzing storage project. (See PD card in Exhibit 7.)

PTC (2) - time of project construction in years. Used to estimate interest during construction. (See CF card in Exhibit 7.)

QDES (0) - total plant design capacity in cfs or cms. (See PD card in Exhibit 7.)

QFACT (1.0) - decimal fraction that is used to adjust the streamflow ordinates of the streamflow-duration curve. (See PQ card in Exhibit 7.)

QMIN (0) - minimum operating discharge limit for the installed unit(s). (See PQ card in Exhibit 7.)

QQ - array containing the streamflow value of the streamflow-duration curve. (See QQ card in Exhibit 7.)

QSUB (0) - discharge value where tailwater effects preclude power operation. (See PQ card in Exhibit 7.)

RAAE (1.0) - ratio, expressed as a decimal fraction, which is applied to the machine-determined average annual energy value. (See PB card in Exhibit 7.)

RATE (.06875) - discount rate used in amortizing total investment costs. (See CF card in Exhibit 7.)

REPL (.0125) - replace cost factor, expressed as a decimal fractional part of powerhouse costs. (See CF card in Exhibit 7.)

RESA (0) - user-supplied reservoir area in acres or square kilometers used in the determination of reservoir clearing costs. (See Cl card in Exhibit 7.)

SEAEND (FALSE) - logical variable indicating whether a seasonal power analysis is complete. (.TRUE. implies yes).

SEBR (.50) - energy benefit reduction factor, expressed as a decimal fraction, which is applied to the firm energy benefit factor to determine secondary energy benefits. (See PB card in Exhibit 7.)

SRP (.85) - streamflow reliability factor used in the determination of dependable capacity. (See PB card in Exhibit 7.)

T - logical array that indicates whether any of the four title cards (T1, T2, T3 or T4) in the TITLE (20,4) array have been previously defined. When T(i) is true the program will print the T_i card contained in the TITLE (20,i) array. T(i) should be specified as false when the T_i card is not defined.

TE - array containing efficiencies that will be related to power discharge. (See TE card in Exhibit 7.)

TERM (-999) - termination code used in reading streamflow values from QQ cards. (See FM card in Exhibit 7.)

TH - array containing headwater elevations that will be related to reservoir inflows. (See TH card in Exhibit 7.)

TITLE - array containing title information supplied by the user on T1 through T4 cards.

TQ - array containing flow values that will be related to information contained in the TE, TH, and TW arrays.

TRACE (0) - cumulative trace code used for displaying internal computer computations.

TURB (0) - turbine-type indicator. (See C1 card in Exhibit 7.)

TW - array containing tailwater elevations that will be related to turbine discharges. (See TW card in Exhibit 7.)

UAPF (1.0) - plant factor related to firm energy delivery. (See PD card in Exhibit 7.)

WYL (0) - user-supplied waterway length used to determine waterway costs. (See C1 card in Exhibit 7.)

WYQ (0) - user-supplied waterway design flow used to determine waterway costs. (See C1 card in Exhibit 7.)

XTRP1 - extrapolation variable used in powerhouse cost routine.

XTRP2 - extrapolation variable used in powerhouse cost routine.

XUNITS (0) - number of units comprising total installed capacity of the plant. (See PD card in Exhibit 7.)

2. Variables used in common block POWOUT. These variables are returned to this common block for each capacity size tested.

AAE - average annual energy in MWH.

AAEC - average annual energy cost in dollars per MWH.

ACB - annual capacity benefit in dollars per year.

AEB - annual energy benefit in dollars per year.

AEFF - efficiency of plant.

AELC - average annual energy that is lost due to insufficient generating capability in MWH.

AELQ - average annual energy that is lost due to insufficient penstock capacity in MWH.

AFE - annual firm energy in MWH.

AHEAD - average power head in feet or meters.

AHEADW - average headwater elevation in feet or meters.

ADP - annual plant factor expressed as a decimal fraction.

AQ	-	average annual inflow in cfs or cms.
AQGEN	-	average annual flow used for generation in cfs or cms.
ASE	-	average annual secondary energy in MWH.
ATAILW	-	average tailwater elevation in feet or meters.
BCR	-	benefit to cost ratio.
CAPCTY	-	installed capacity determined by the program in KW.
CBX	-	dependable capacity benefit in $/KW-YR.
DC	-	dependable capacity in KW.
DHEAD	-	design head in feet or meters associated with the installed capacity.
EBX	-	firm energy benefit in $/MWH.
IC	-	interruptible capacity in KW.
ICB	-	interruptible capacity benefit in $/KW-YR.
ICC	-	installed capacity cost in $/KW-YR.
QDES	-	design discharge in cfs or cms associated with the installed capacity.
TAB	-	total annual benefits in $/YR.
TAC	-	total annual costs in $/YR.
TANB	-	total annual net benefits in $/YR.
EQF	-	equivalent firm energy in MWH.

EXHIBIT 2

ADJUSTMENT OF FLOW-DURATION CURVE FOR STORAGE EFFECTS

A) DEVELOPMENT OF METHODOLOGY

The analysis of hydropower storage projects has traditionally been performed by use of sequential reservoir routing techniques. The use of flow-duration techniques has been traditionally applied only to run-of-river type projects.

While individual power storage projects should be analyzed by detailed sequential routings when sufficient funds and detail are available, the flow-duration technique (as modified herein) can be made to somewhat approximate the results of a sequential routing by modifying the flow-duration curve to represent outflow conditions.

A storage project, in general, accumulates excessive inflows for future use during low-flow periods, thereby transforming the inflow-duration curve, based on inflows into the project, into a flatter outflow-duration curve, reflecting the operation and effect of the project's storage as depicted below:

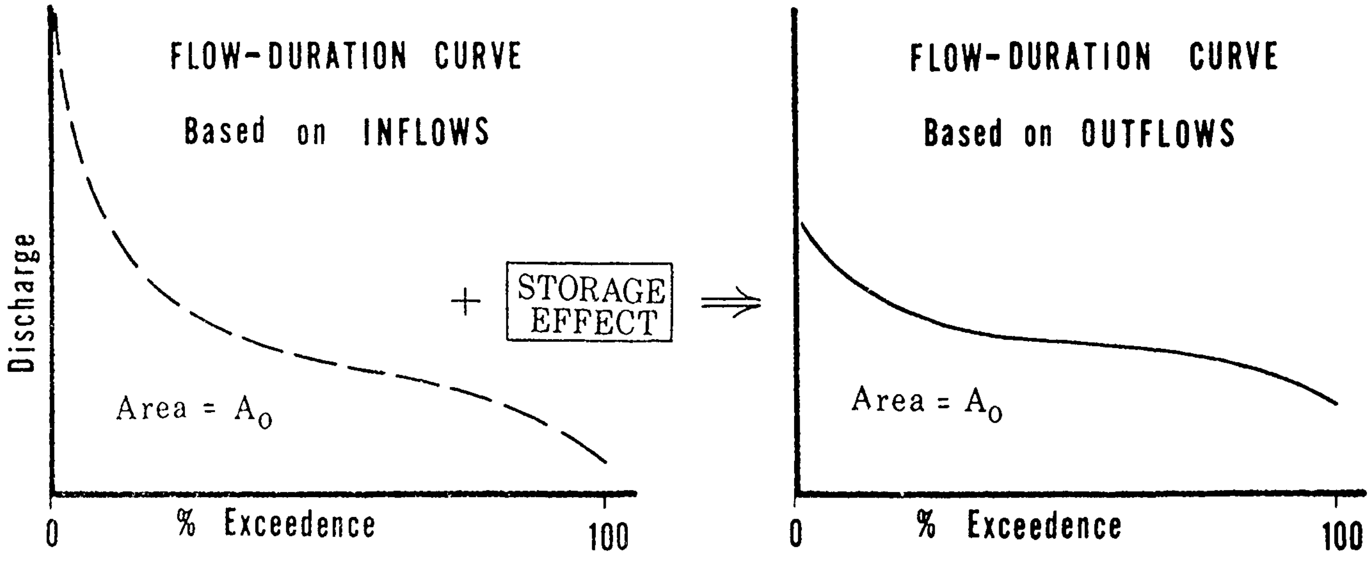


Figure 1

Superimposing the previous curves results in:

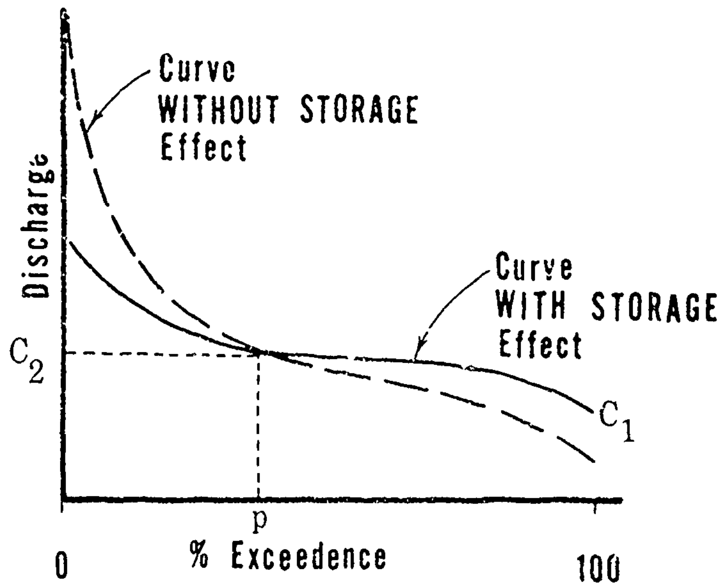


Figure 2

where the area (A_0) under the original flow-duration curve is preserved and the modified flow-duration curve passes through points C_1 and C_2, where

C_1 represents a discharge corresponding to 100 percent exceedence;

C_2 represents a point of intersection between the two curves.

The following analytical technique was developed to determine the transformed shape of the flow-duration curve that satisfies the above conditions. The criteria used in making a selection of C_1 and C_2 will be discussed later.

Restated, the problem requires the development of an algorithm that will generate a modified flow-duration curve and meet the following conditions:

1) the value of the function (flow-duration ordinate) at 100 percent exceedence must be C_1;

2) the value of the function (flow-duration ordinate) at some percent exceedance p must be C_2, where $0 < p < 1.0$;

3) the area under the modified flow-duration curve must equal the area under the original flow-duration curve (A_0).

The first assumption made in the technique is to decide the mathematical form of the function to be used. Since flow-duration curves resemble decaying power functions the following generalized function was assumed:

$$Q(x) = AD^{(B(1-x))} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 1}$$

where A = multiplying coefficient;

D = a base value;

B = a power coefficient;

and where x = the percent exceedence corresponding to discharge (Q), where x is expressed as a fraction between 0 and 1.

After initial testing, it was found that the assumed power function could only satisfy any two of the three conditions required. Therefore, the analytical form was modified to:

$$Q(x) = A\ 10^{(B(1-x))} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. 2}$$

where A = multiplying coefficient;

B = a power coefficient;

and where x = the percent exceedence correspondence to discharge (Q), where x is expressed as a fraction between 0 and 1.

Eq. 2 can now be used to define a relationship which passes through points C_1 and C_2 designated as $Q1(x)$. The same mathematical form can be used to develop another relationship designated as $Q2(x)$, which passes through C_2 in such a manner as to ensure the area under both curves is A_o.

The necessary conditions can be restructured as follows:

1) Define a function ($Q1(x)$) such that $Q1(1.0) = C_1$ and $Q1(p) = C_2$;

2) Determine the area under $Q1(x)$ from $x = p$ to $x = 1.0$ and call the area A_1;

3) Define another function ($Q2(x)$) such that $Q2(p) = C_2$ and the area under the curve from $x = 0$ to $x = p$ (designated as A_2) is equal to the original area A_o minus A_1.

The following illustrates the above requirements:

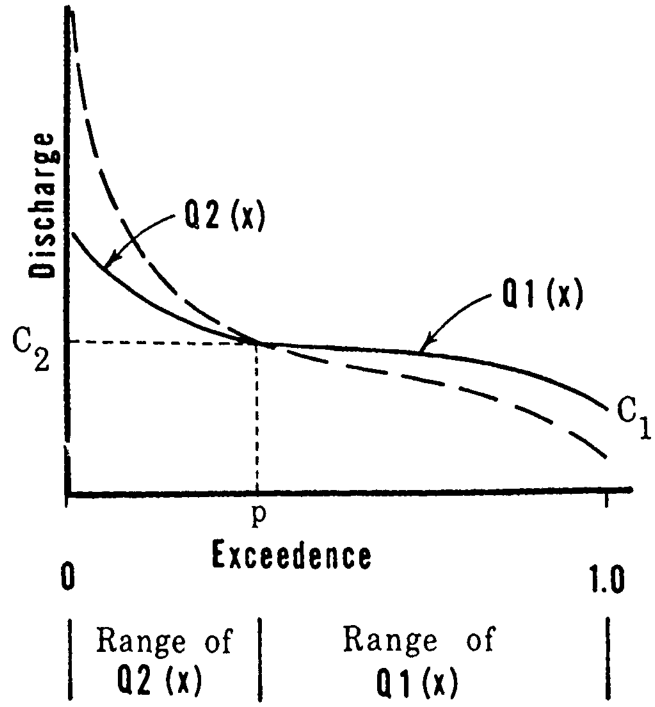


Figure 3

The coefficients A and B for function (Q1(x)) can be determined by satisfying condition (1):

$A = C_1$ .... Eq. 3

$B = LOG(C_2/C_1)/\ (1 - p)$ .... Eq. 4

Integrating Q1(x) from x = p to x = 1.0 yields the following for condition (2):

$A_1 = (C_1/(2.3B))(10^{(B(1-p))}-1)$ .... Eq. 5

To this point in the technique, a relationship for the modified flow-duration curve from x = p to x = 1.0 has been developed and the area under this segment of the curve has been determined. The function (Q2(x)) must satisfy the remaining condition (3):

Integrating Q2(x) from x = 0 to x = p, and noting that the function (Q2(x)) must pass through C_2 at x = p yields:

$A_2 = A_o - A_1$ .... Eq. 6

$2.3A_2/C_2 = [10^{(Bp)}-1]\ /B$ .... Eq. 7a

There is no direct solution for B in Equation 7a; however, a value for B can be obtained by use of Newton's first order approximation. This trial and error solution is conditional upon C_2 being within an acceptable range (i.e., there exists some values MN and MX, such that $MN < C_2 < MX$ is a condition necessary for solution of B).

A requirement for the use of the first-order approximation technique is an estimate of the first derivative of Equation 7a. Closer inspection of Equation 7a, reveals the expression can be simplified since A_2 and C_2 have been previously determined:

$F(Bp) = ((10^{(Bp)} - 1)/B) - K$ .... Eq. 7b

where $K = 2.3A_2/C_2$

Substituting the dummy variable u = Bp yields:

$F(u) = p((10^u - 1)/u) - K$ .... Eq. 8

Taking the first derivative of F(u) results in the following:

$\frac{dF(u)}{du} = p\ (2.3u10^u - 10^u + 1)/\ u^2$ .... Eq. 9

Of interest is where the first derivative equals zero (corresponds to the minimum value of u). Solving Equation 9 for zero results in u approaching zero in the limit, since at u = 0, Equation 9 is undefined.

An algorithm can now be devised to generate the modified flow-duration curve as outlined below, given the area A_o and parameters C_1 and C_2. (Knowing C_2 implies knowing p).

1) Solve the coefficients A and B in power function (Q1(x)) by using estimates C_1 and C_2 in Equations 3 and 4;

2) Determine the area under function (Q1(x)) using Equation 5 and call result A_1;

3) Determine the remaining required area needed under function (Q2(x)) from Equation 6 and call result A_2;

4) Calculate the K component of Equation 7b using results from step 3 and the estimate of C_2;

5) Test to see if the minimum value for u, say u = 0.01, results in a value less than K. If not, make new estimate of C_2 and return to Step 1;

6) Use Equation 9 to make new estimate of u and continue process until the estimate of u results in Equation 8 equaling zero.

B) PARAMETER DETERMINATION

Attention is now focused on making estimates for parameters C_1, C_2 and p. The value of A_0 is a constant and represents the area underneath the original flow-duration curve, which is easily determined by integration.

The value of C_2 has been shown to be critical in a final feasible solution of the problem. This parameter will be systematically set equal to A_0, which generally corresponds to percent exeedences ranging in value from 15 to 35 percent. The selection for C_2 will automatically determine the value of p since C_2 and p are functionally related through use of the flow-duration relationship. Therefore, a means of selecting a value for C_1 is the only obstacle remaining in defining a plausible solution.

The value of C_1 is dependent on the storage capability of the site being analyzed. Accordingly, it seems reasonable to assume that C_1 can be estimated by considering the base flow component of the flow regime and the minimum flow contribution due to reservoir regulation during adverse flow conditions as follows:

C_1 = QMC + QMSC..Eq. 10

where:

C_1 = the minimum flow value on the synthetic flow-duration curve corresponding to 100 percent exceedence;

QMC = the minimum flow value on the original flow-duration curve without regard to storage effects (100 percent exceedence value);

QMSC = the minimum flow contribution attributed to reservoir operation under critical low inflow conditions.

Critical low flow conditions occur whenever, over a sustained period of time, a reservoir is regulated to release additional flow in excess of upstream inflows as a means of satisfying designed project purposes. With regard to hydropower, this operational policy, if continued, can actually exaggerate the situation since depletion of power storage reduces the effective headwater and correspondingly the operating power head; requiring a continually increasing amount of flow to sustain energy requirements. The period of maximum drawdown can be defined as the period of time which begins with full power storage and ends when the power storage remaining is at a minimum. By definition, the period of maximum drawdown will then contain the most adverse streamflow conditions and will require the maximum withdrawal of water from the power storage. An estimate of QMSC can now be approximated by determining the depletion rate occurring throughout this period.

As an initial step, the power storage can be converted from units of volume, typically in acre-feet, to units of flow rate (cfs). To perform this conversion, a time period, say one year, must be selected. The resulting value expresses the power storage potential as the average amount of flow that can be extracted from an initially full power pool throughout a period of one year.

However, as defined above, the period of maximum drawdown is unconstrained with regard to the length of time required to complete the process, and actual reservoir operations have demonstrated this period of time varies from a few weeks to several years in length. Accordingly, the initial depletion rate (assuming a one-year length in the period of maximum drawdown) must be adjusted by a factor to reflect the project's actual length in time to minimum pool level as shown below:

QMSC = PS * ACF * ADJF......................................Eq. 11

where

PS = power storage expressed as a volume (acre-feet);

ACF = a conversion factor (0.00138) which when multipled by (PS) expresses the amount of power storages in terms of an average annual flow rate (CFS-YR);

ADJF = adjustment factor applied to the power storage to correct for variation in the length of the period of maximum drawdown.

From Equation 11, one can conclude that a length of the period of maximum drawdown exceeding one year requires the adjustment factor (ADJF) to be less than one, since a factor failing this requirement will cause QMSC to be overestimated. Conversely, a length in the period of maximum drawdown less than unity requires ADJF to exceed unity. In effect, ADJF can be alternatively defined as the reciprocal of the length in the period of maximum drawdown, when time is measured in years.

Several attempts at establishing a relationship to determine a value for ADJF were performed. The regression equation finally selected is based upon 113 existing and proposed hydro sites throughout the United States and is shown below:

$$\text{ADJF} = 0.65 + 1.113 * \text{LOG}(1/\text{PSR}) \quad \text{.......................Eq. 12}$$

where PSR represents a project's power storage to mean annual flow ratio.

Statistically, the above equation resulted in a R-squared value of 0.49 and a standard error of 0.45. A plot of this relationship can be seen in Figure 4.

The PSR is a dimensionless parameter which expresses the relative size of power storage to average annual inflow and is determined by converting power storage to an average one year flow rate, as previously suggested, and then dividing the result by the project's expected average annual inflow.

A relatively large PSR, say greater than 1.0, indicates sufficient storage capacity so that, on the average, there exists the capability of extending the period of maximum drawdown during sustained periods of low inflow. As the PSR falls below 1.0, this capability to attenuate diversity between inflow availability and project demands decreases, causing the average length of the period of maximum drawdown to decrease, accordingly. Another observation in Figure 4, substantiating this conclusion, is that as the PSR falls below 1.0, considerable increase in scatter of the data occurs, implying that the decreasing storage capability is becoming relatively less effective in controlling the diversity between inflow supply and energy demand. A direct determination of parameter C_1 is now possible by successive use of Equations 12, 11, and 10; allowing for a plausible solution to systematically producing a synthetic flow-duration relationship for projects exhibiting power storage.

The substitution of the relationship for the original flow-duration curve will substantially improve any estimate of average energy and will additionally enable an approximation of dependable capacity to be performed when used in a nonsequential power potential analysis.

Dependable capacity can be defined as the capacity which under the most adverse flow conditions on record, can be relied upon to carry system load, provide dependable reserve capacity, and meet firm power obligations, taking into account seasonal variations and other characteristics of the load to be supplied. The association to the "most adverse flow conditions on record," in the definition of dependable capacity strongly supports the notion that parameter C_1 might be valuable as an indicator in approximating this capacity value. This assumption was tested and it was found that dependable capacity could be estimated by using the power equation as follows:

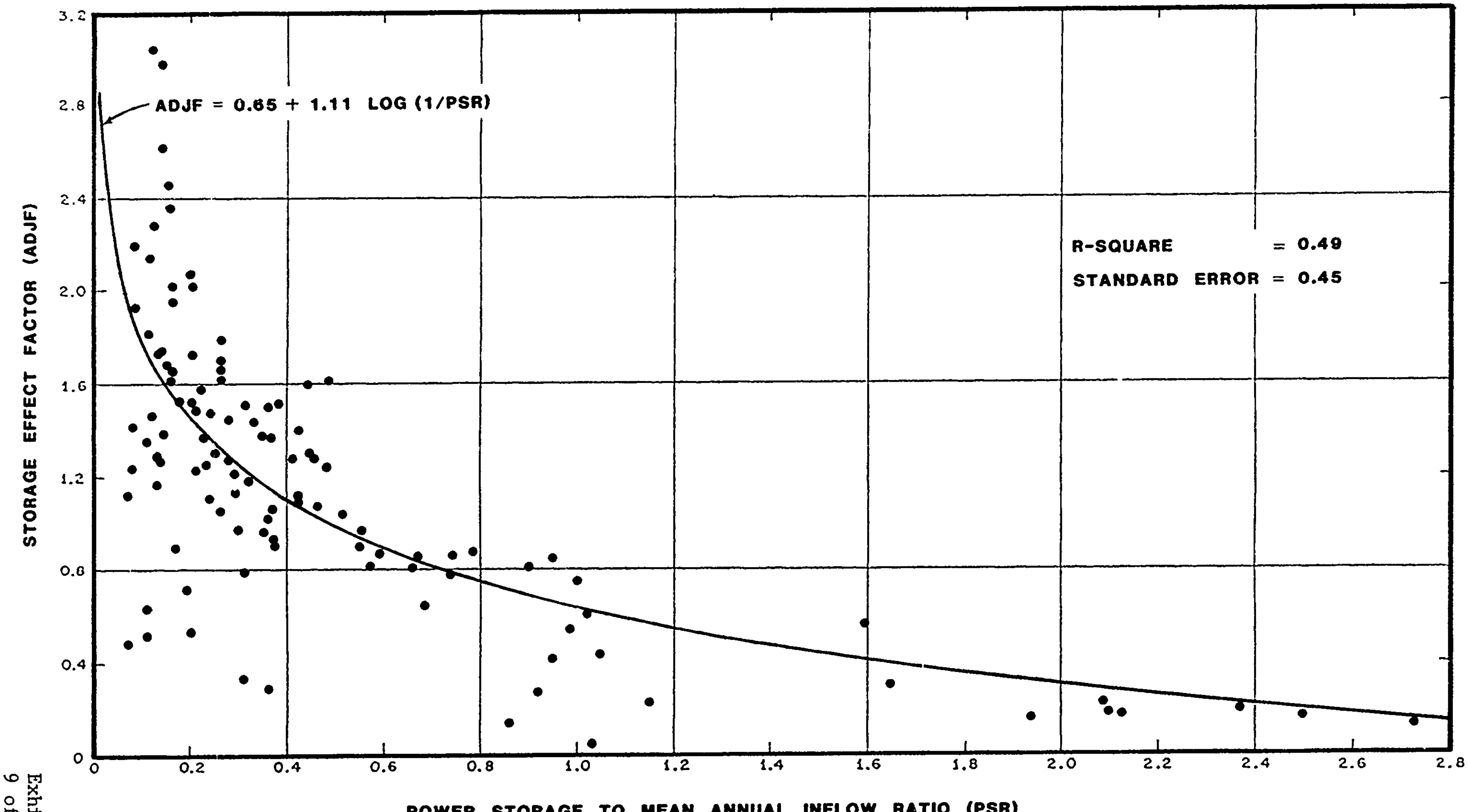


FIGURE 4 PLOT OF REGRESSION ANALYSIS RESULT

$$DCAP = C(C_1/PF)He \qquad \text{Eq. 13}$$

where:

DCAP = dependable capacity in kilowatts;

C = .084603 conversion factor which expresses power in kilowatts;

C_1 = the minimum flow parameter as previously defined;

PF = the average annual plant factor relating dependable capacity to its firm energy requirement;

H = net power head in feet;

e = overall efficiency (assumed equal to a constant 0.86)

The quantity (C_1/PF) represents the expected minimum flow adjusted for average time of hydropower plant operation.

Equation 13 was employed with data from all 113 projects used to develop the parameter ADJF and the resulting estimates of dependable capacity were compared to corresponding dependable capacity values estimated from sequential routing techniques.

This comparison, depicted in Figure 5, resulted in an R-squared value of 0.985 and a standard error of 10,700 kilowatts. Comparison of empirical to sequentially determined capacities varied over a range of 100 kilowatts to 650 megawatts. A departure in plotting position above an imaginary 45° line represents an underestimate of dependable capacity determined empirical as compared to dependable capacity estimated using sequential routing techniques. Conversely, a departure below this line represents an exaggeration of dependable capacity. Maximum departure about this line, in terms of percent difference, occurs for small installations (i.e., project having installed capacities less than 2 megawatts). Small installations are generally associated with projects possessing limited storage capacity and correspondingly small power storage to mean annual flow ratios (PSR). Since the regression equation used to estimate ADJF (Equation 12) was incorporated in the empirical determination of dependable capacity, the problem of increased scatter associated with small PSR's is most probably the underlying influence causing these maximum departures to occur in this capacity range.

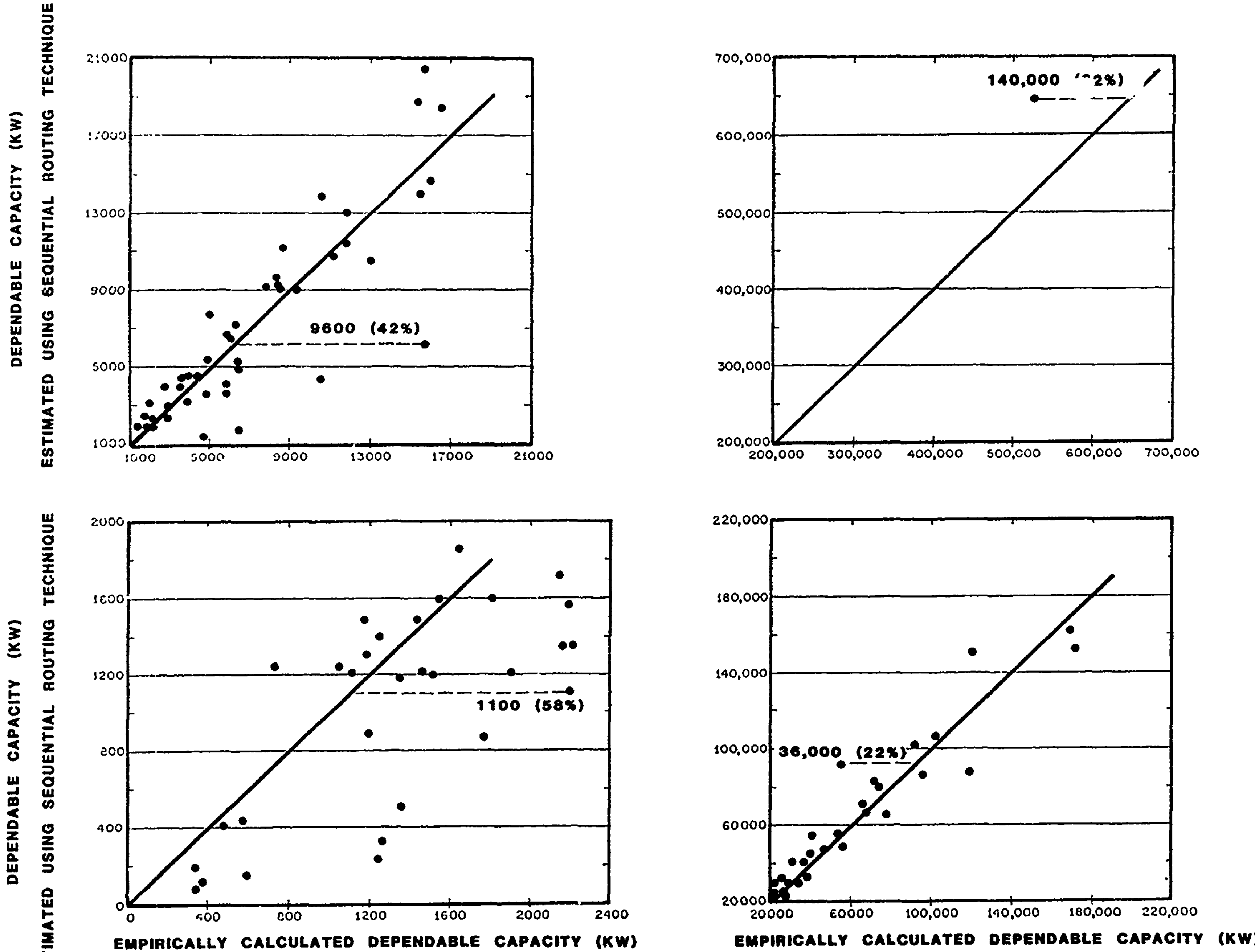


FIGURE 5 COMPARISON OF EMPIRICAL TO SEQUENTIALLY DETERMINED DEPENDABLE CAPACITIES

Example Problem Illustrating The Use of
Synthetic Flow-Duration Curve Techniques

A :ume the following hydrologic data can be developed for a site:

1) power storage (PS) = 42,783 acre-feet

2) net power head (H) = 148 feet

3) dependable capacity plant factor APF = 0.6017

4) estimate of dependable capacity from sequential analysis = 1,049 Kw

5) original flow-duration curve (see Figure 6)

A) Estimate of Dependable Capacity

Step 1 - Integrating the flow-duration curve yields an average annual flow (AAQ) of 95.22 cfs

Step 2 - Determine power storage to mean flow ratio (PSR)

PSR = PS * 0.00138/AAQ

PSR = 42783 * .00138/95.22 = 0.62

Step 3 - Use PSR and regression equation to find ajustment factor ADJF

ADJF = 0.65 + 1.113 LOG(1/PSR) = 0.88

Step 4 - Calculate minimum contribution of flow due to storage regulation (QMSC)

QMSC = PS*.00138 * ADJF

QMSC = 42783 * .00138 * .88 = 52.02 cfs

Step 5 - Find total minimum flow (C_1)

C_1 = QMC + QMSC

C_1 = 1.05 + 52.02 = 53.07 cfs

Example Problem Illustrating The Use of
Synthetic Flow-Duration Curve Techniques
(continued)

Step 6 - Determine dependable capacity DCAP

$$DCAP = (C_1/ADF) * H * C * e$$

$$DCAP = (53.07/0.6017) * 148 * 0.084603 * 0.86$$
$$= 951 \text{ KW}$$

Note: Ratio of dependable from sequential and algorithm = 1049/951 = 1.10

B) Synthetic flow-duration curve algorithm

Step 1 - Select cross-over point between curves (C_2) at percent exceedence corresponding to AAQ

$$C_2 = AAQ = 95.22 \text{ cfs}$$

Note: C_2 corresponds to percent exceedence (p). Approximately 30 percent (see Figure 6)

Step 2 - Determine decaying power function Q1(x) from Q1(.30) to Q1(1.0)

$$A = C1 = 53.07$$

$$B = LOG(C_2/C_1)/(1-p)$$

$$B = LOG\ (95.22/53.07)(1-0.3)$$

$$B = 0.36$$

therefore Q1(x) = 53.07*10**(0.36(1-x))

Step 3 - Determine area under Q1(x) from x = 0.30 to x = 1.0

$$A_1 = (C_1/(2.3 * B)) * (10**(B(1-p))-1)$$

$$A_1 = (53.07/(2.3 * 0.36) * (10**(0.36(.7))-1)$$

$$A_1 = 50.59 \text{ cfs}$$

Example Problem Illustrating The Use of
Synthetic Flow-Duration Curve Techniques
(continued)

<u>Step 4</u> - Determine area under Q2(x) from x = 0 to x
x = .30

A_2 = AAQ - A_1 = 95.22 - 50.59 = 44.63 cfs

<u>Step 5</u> - Determine decaying power function Q2(X) from
x = 0 to x = 0.30

$K = 2.3 * A_2/C_2$

$K = 2.3(44.63)/95.22 = 1.08$

using Newton's 1st order approximation solve for
$F(u) = 0$

where

$F(u) = p((10^u-1)/u) - K$

1/ $F'(u) = p(2.3u10^u - 10^u + 1)/u^2$

and p = 0.30

1st Guess: try u = 1.0

$F(1.0) = .3(10-1)/1 - 1.08 = 1.62$

since $F(1.0) \neq 0$, try again

$F'(1.0) = 0.3(2.3(10) - 10 + 1)/1 = 4.20$

2nd Guess $u = u - F(u)/F'(u) = 1 - 1.62/4.20 = 0.61$

$F(0.61) = 0.3(10^{.61} - 1)/0.61 - 1.08 = 0.432$

since $F(0.61) \neq 0$, try again

$F'(0.61)=0.3(2.3(.61)\, 10^{.61} - 10^{.61} +1)/(.61)^2 = 2.130$

1/ F'(u) implies the first derivative of function F(u) with respect to u.

Example Problem Illustrating The Use of
Synthetic Flow-Duration Curve Tec.niques
(continued)

3rd Guess $u = 0.61 - 0.432/2.130 = 0.41$

$F(0.41) = 0.3\ (10^{.41} - 1)/0.41 - 1.08 = 0.069$

since $F(0.41) \neq 0$ try again

$F'\ (0.41) = 0.3\ (2.3(.41)\ 10^{.41} - 10^{.41} + 1)/(.41)^2 = 1.523$

4th Guess $u = 0.41 - .069/1.523 = 0.36$

$F(0.36) = 0.3(10^{.36} - 1)/.36 - 1.08 = -0.004$

since $F(0.36)$ is ≈ 0, iterative process completed. Recalling $u = Bp$ and $p = 0.30$, then;

$B = 0.36/.3 = 1.20$

By definition, at $x = p$, $Q2(x) = C_2$. Therefore, by substitution of these parameters in function (Q2(x)) yields:

$A = C_2/10^{(B - Bp)} = 95.22/10^{.84} = 13.76$

Parameter A and B for Q2(x) are now determined, therefore,

$Q2(x) = 13.76 * 10^{(1.20(1-x))}$

Use of Q1(x) and Q2(x) will duplicate synthetic curve depicted in Figure 6.

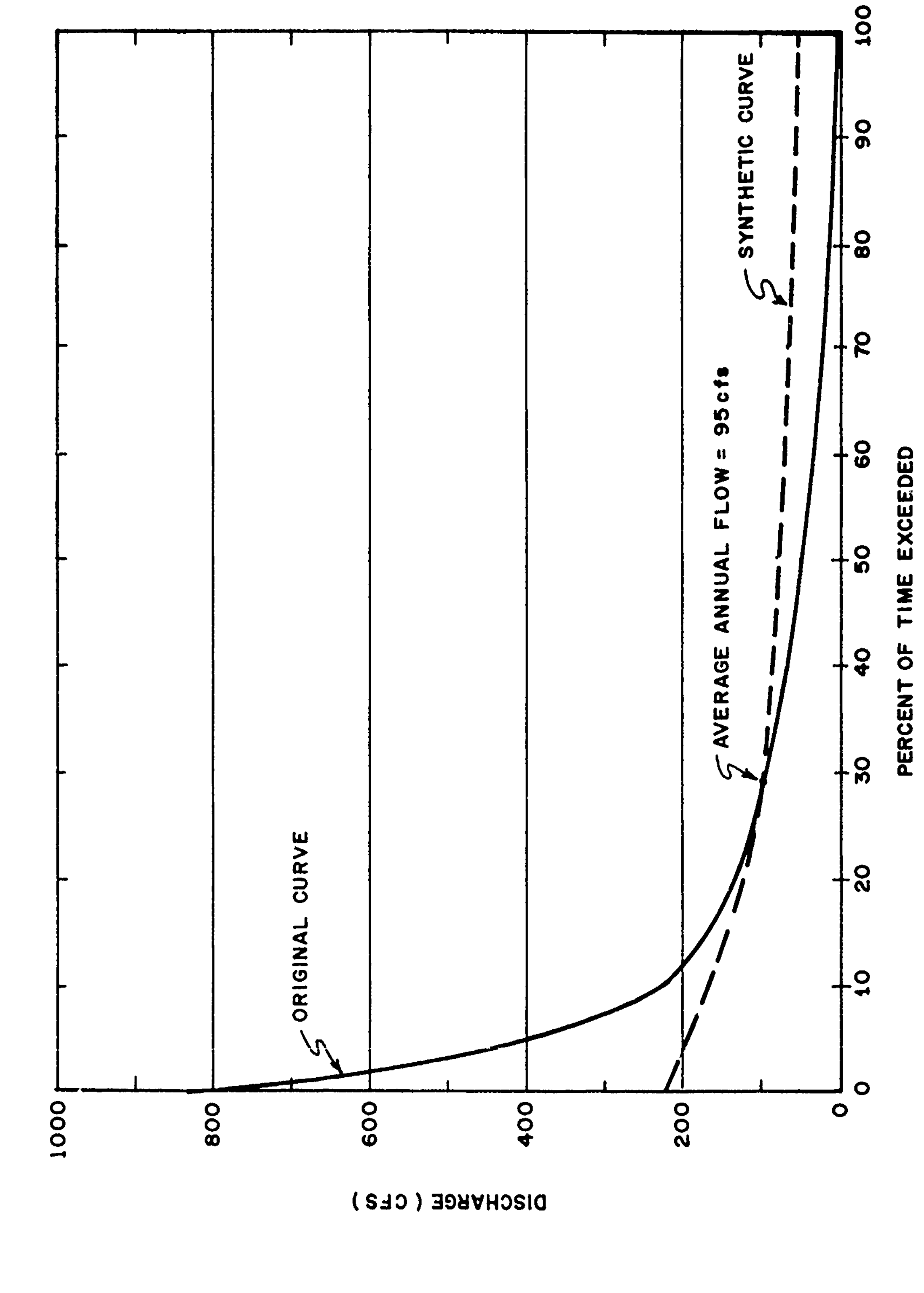


Figure 6. GRAPHICAL REPRESENTATION OF EXAMPLE

EXHIBIT 3

TEST PROBLEMS

The test problems of this exhibit are included to illustrate selected analytical capabilities, input requirements, and output format of the HYDUR program. The problems are also intended for use in verification of distributed program code. Four problems are included to demonstrate a range of potential applications of the HYDUR program. Specific problem statements, description of input requirements, and results are provided for each problem.

1. TEST PROBLEM - SITE ASSESSMENT FOR ENERGY CAPACITY

This test problem presents a basic application of the HYDUR program. The problem depicts a preliminary assessment of the feasibility of installing 100,000 kilowatt (PD.4) generating capacity at an existing reservoir designed and operated for irrigation purposes. Two units (PD.8) of 50,000 kilowatts each are analyzed. The flow duration curve is input directly in standard format of 10F8.0 as specified on the FD card. The last value of the flow-duration data is followed by a -999 which indicates the end of the data set. The following assumptions were made with respect to this test problem.

1) The maximum penstock discharge capacity is input as 7710 cfs (PD.1).

2) The powerplant efficiency is estimated to be .86 (PD.2).

3) An overload factor of 1.2 (PD.5) was input.

4) An upstream diversion of 47.35 cfs (PQ.3) exists that includes a water supply requirement and net evaporation. This loss will be subtracted from available power flow values but will not affect power operating head.

5) A diversion loss (leakage) of 10 cfs was input (PQ.4) to account for flow losses that would not contribute to power production (through the penstocks) but would affect tailwater elevations. NOTE: For this problem with a constant input head of 175 feet tailwater elevations will not fluctuate.

6) An adjustment factor of .958 (PQ.5) was input to account for the difference in discharge value (drainage area ratios) between the downstream gage and the damsite. This value is multiplied times each streamflow value.

7) A set of TQ, TH, and TW cards were used to define tailwater conditions.

The results of the analysis indicate that 132,977 MWH of average annual energy could be generated by the two 50,000 KW units. The facility would use a calculated average outflow of 1200 cfs for power generation.

FLOW DURATION INPUT

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           T1                                   TEST 1
  2           T2                    PRELIMINARY ANALYSIS OF POTENTIAL HYDROPOWER SITE
  3           T3                        TWO UNITS WITH TOTAL CAPACITY OF 100000KW CAPACITY
  4           T4      MONTHLY STREAMFLOWS IN STANDARD FORMAT, USGS GAGE 7339000, 1930-1967
  5           FD      CARD       STD
  6                   .976      1.00      .974      1.26      .974      1.58      .967      2.00      .963      2.51
  7                   .961      3.16      .958      3.98      .952      5.01      .947      6.31      .941      7.94
  8                   .939      10.0      .934      12.6      .925      15.8      .910      20.0      .888      25.1
  9                   .884      31.6      .875      39.8      .849      50.1      .846      63.1      .827      79.4
 10                   .785      100.      .770      126.      .761      158.      .719      200.      .691      251.
 11                   .651      316.      .618      398.      .575      501.      .535      631.      .487      794.
 12                   .421     1000.      .377     1259.      .325     1585.      .243     1995.      .156     2512.
 13                   .101     3162.      .057     3981.      .037     5012.      .020     6310.      .007     7943.
 14                   .002    10000.    0.        12589.-999.000        0.
 15           PD      7710       .86              100000       1.2                          2.0
 16           PQ                         47.35        10      .958
 17           TQ         0      3000      9000    105000    289000
 18           TH     577.5
 19           TW     400.0     404.0     408.0     440.0     457.0
 20           EJ
```

```
JSTATE ON C2 CARD OMITTED -- COST ANALYSIS INHIBITED
********************************************************************************
                                TEST 1
              PRELIMINARY ANALYSIS OF POTENTIAL HYDROPOWER SITE
                  TWO UNITS WITH TOTAL CAPACITY OF 100000KW CAPACITY
     MONTHLY STREAMFLOWS IN STANDARD FORMAT, USGS GAGE 7339000, 1930-1967
JOB NUMBER    1
********************************************************************************

IMPLICIT STANDARD UNITS OF MEASUREMENTS

                        LENGTH      POWER      ENERGY    CURRENCY   DISCHARGE        TIME
             ENGLISH    (FOOT)      (KW)       (MWH)     (DOLLAR)     (CFS)          (YR)
              METRIC   (METER)      (KW)       (MWH)     (DOLLAR)     (CMS)          (YR)


AF CARD       SYSTEM      DISPLAY ADJUSTMENT FACTORS APPLIED TO STANDARD UNITS
                          ALEN       APWR      AENRG      ADOLR      AFLOW         TIME
              ENGLSH     1.0000     1.0000     1.0000     1.0000     1.0000       1.0000

FLOW DURATION CURVE INPUT

FD CARD        FTYPE     FMTYPE      PUNCH     ISTATE     IGAUGE
                CARD        STD         NO          0          0

 UNADJUSTED FLOW DURATION CURVE -- FLOWS IN (CFS/CMS) AND EXCEEDENCE PROBABILITIES AS DECIMAL FRACTIONS

PE            0.9760     0.9740     0.9740     0.9670     0.9630     0.9610     0.9580     0.9520     0.9470     0.9410
QQ              1.00       1.26       1.58       2.00       2.51       3.16       3.98       5.01       6.31       7.94

PE            0.9390     0.9340     0.9250     0.9100     0.8880     0.8840     0.8750     0.8490     0.8460     0.8270
QQ             10.00      12.60      15.80      20.00      25.10      31.60      39.80      50.10      63.10      79.40

PE            0.7850     0.7700     0.7610     0.7190     0.6910     0.6510     0.6180     0.5750     0.5350     0.4870
QQ            100.00     126.00     158.00     200.00     251.00     316.00     398.00     501.00     631.00     794.00

PE            0.4210     0.3770     0.3250     0.2430     0.1560     0.1010     0.0570     0.0370     0.0200     0.0070
QQ           1000.00    1259.00    1585.00    1995.00    2512.00    3162.00    3981.00    5012.00    6310.00    7943.00

PE            0.0020     0.0000
QQ          10000.00   12589.00


POWER GENERATION PARAMETERS

PD CARD   MAX PEN Q  DESIGN EFF DESIGN HEAD   INST CAP   OVERLOAD  ANN PLANT POWER STORE  NUMBER OF    PEAKING
            CFS/CMS                 FT/MT         KW      FACTOR     FACTOR       RATIO    UNIT(S)     FACTOR
             (QDES)      (EFF)     (HEAD)   (CAPDES)   (OVLOAD)     (UAPF)       (PSR)  (XUNITS)    (PEAKF)
            7710.00     0.8600       0.00  100000.00      1.200      1.000       0.000     2.000      1.000

PQ CARD SUBMERGENCE   MIN FLOW  DIVERSION    TW LOSS FLOW RATIO   MIN HEAD    MAX HEAD     SPILL
            CFS/CMS    CFS/CMS    CFS/CMS    CFS/CMS                 FT/MT       FT/MT    EFFECT
             (QSUB)     (QMIN)      (DIV)    (QLOSS)    (QFACT)     (HMIN)      (HMAX)   (SPLEF)
               0.00       0.00      47.35      10.00      0.958       0.00   100000.00       YES

TABLE OF DISCHARGE (CFS/CMS) VS. EFFICIENCY, HEADWATER AND TAILWATER (FT/MT)

TQ CARD        0.00    3000.00    9000.00  105000.00  289000.00  578000.00 1156000.00 2312000.00 4624000.00 9248000.00
TE CARD       0.860      0.860      0.860      0.860      0.860      0.860      0.860      0.860      0.860      0.860
TH CARD      577.50     577.50     577.50     577.50     577.50     577.50     577.50     577.50     577.50     577.50
TW CARD      400.00     404.00     408.00     440.00     457.00     457.00     457.00     457.00     457.00     457.00
```

BENEFIT CALCULATION PARAMETERS

PB CARD	REGION CODE (IREG)	CAP BEN RATIO (CBR)	DEP CAP KW (DCAP)	INPUT AAE MWH (AAEST)	AAE RATIO (RAAE)	STREAMFLOW RELIABILITY (SRP)	ENERGY RATIO (ERATIO)	CAPACITY RATIO (CRATIO)	ENERGY BEN RATIO (SEBR)
	0	0.500	0.00	0.00	1.000	0.850	1.000	1.000	0.500

NO CAPACITY BENEFIT VALUES PROVIDED -- BENEFIT ANALYSIS INHIBITED
ENTER CB CARD OR IREG ON PB CARD

NO ENERGY BENEFIT VALUES PROVIDED -- BENEFIT ANALYSIS INHIBITED
ENTER EB CARD OR IREG ON PB CARD

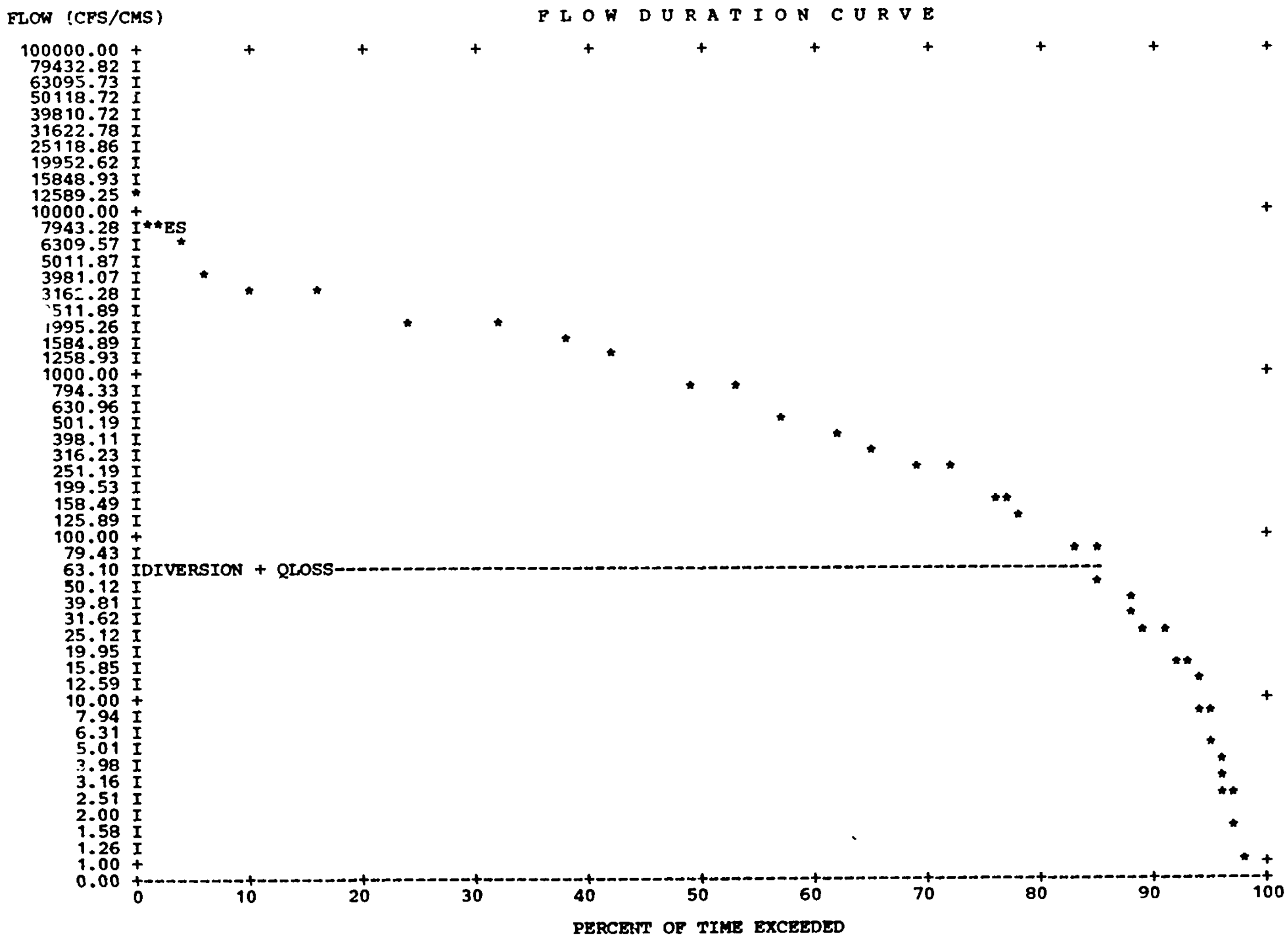
COST CALCULATION PARAMETERS
($ AMOUNTS X 1000)

C1 CARD	DAM HEIGHT FT/MT (HEIGHT)	DAM LENGTH FT/MT (DIST)	VALLEY SHAPE (KS)	EXIST CAP KW (ECAP)	OPERATION MODE (OPER)	TURBINE (TURB)	RES AREA ACRE/SQ KM (RESA)	WATERWAY L FT/MT (WYL)	WATERWAY Q CFS/CMS (WYQ)	COMPONENT CODE (IPROJ)
	0.00	0.00	1	0.	L	0	0.	0.00	0.00	0
C2 CARD	STATE CODE (JSTATE)	IN/OUTLET K$ (CIO)	POWERHOUSE K$ (CPWH)	EMBANKMENT K$ (CEMB)	SPILLWAY K$ (CSPW)	WATERWAY K$ (CWWY)	RES CLEAR K$ (CRC)	ACQUISITION K$ (CLA)	MISC K$ (CMIS)	COST FACTOR (COSTR)
	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.000
CF CARD	CONTINGENCY FACTOR (CONT)	INTEREST (RATE)	AMORTIZE YEARS (AMOR)	TIME OF CONSTRUCT (PTC)	REPLACE FACTOR (REPL)					
	0.25000	0.06875	100.	5.0	0.01250					

PRINT SUPPRESSION

PS CARD	(PLOTS)	(CEFS)	(ECHOS)	(CALCS)	(IPRTS)
	0	0	0	0	0

TEST 1
PRELIMINARY ANALYSIS OF POTENTIAL HYDROPOWER SITE
TWO UNITS WITH TOTAL CAPACITY OF 100000KW CAPACITY
MONTHLY STREAMFLOWS IN STANDARD FORMAT, USGS GAGE 7339000, 1930-1967
JOB NUMBER 1



TEST 1
PRELIMINARY ANALYSIS OF POTENTIAL HYDROPOWER SITE
TWO UNITS WITH TOTAL CAPACITY OF 100000KW CAPACITY
MONTHLY STREAMFLOWS IN STANDARD FORMAT, USGS GAGE 7339000, 1930-1967
JOB NUMBER 1

POWER POTENTIAL RESULTS USING FLOW DURATION TECHNIQUE 30 JUL 82

ITEM NUMBER	MATHEMATICAL EXPRESSION	ITEM DESCRIPTION		POTENTIAL CAPACITY	EXISTING CAPACITY	INCREMENTAL CAPACITY
1	1=1	INSTALLED CAPACITY	KW	100000.00	0.00	100000.00
2	2=2	AVERAGE ANNUAL ENERGY	MWH	132977.92	0.00	132977.92
3	3=2/(8.76*1)	AVERAGE ANNUAL PLANT FACTOR		0.15	0.00	0.15
4	4=F(SRP)	DEPENDABLE CAPACITY	KW	0.00	0.00	0.00
5	5=5	ANNUAL FIRM ENERGY	MWH	0.00	0.00	0.00
6	6=1-4	INTERRUPTIBLE CAPACITY	KW	100000.00	0.00	100000.00
7	7=2-5	ANNUAL SECONDARY ENERGY	KW	132977.92	0.00	132977.92
8	8=5+F(7)	ANNUAL EQUIVALENT FIRM ENERGY	MWH	0.00	0.00	0.00
15	15=15	AVERAGE ANNUAL ENERGY LOST DUE TO INSUFFICIENT PENSTOCK CAPACITY	MWH	241.69	0.00	241.69
16	16=16	AVERAGE ANNUAL ENERGY LOST DUE TO INSUFFICIENT GENERAGING CAPACITY	MWH	235.79	0.00	235.79
17	17=17	DEPENDABLE CAPACITY BENEFIT	$/KW-YR	0.00	0.00	0.00
18	18=CBR*17	INTERRUPTIBLE CAPACITY BENEFIT	$/KW-YR	0.00	0.00	0.00
19	19=19	AVERAGE ANNUAL ENERGY BENEFIT	$/MWH	0.00	0.00	0.00
20	20=4*17 + 6*18	ANNUAL CAPACITY BENEFIT	$/YR	0.00	0.00	0.00
21	21=5*19 + 7*F(19)	ANNUAL ENERGY BENEFIT	$/YR	0.00	0.00	0.00
21	21=8*19 (IF 8¢0)					
22	22=20+21	TOTAL ANNUAL BENEFIT	$/YR	0.00	0.00	0.00
23	23=25/1	INSTALLED CAPACITY COST	$/KW-YR	0.00	0.00	0.00
24	24=25/2	AVERAGE ANNUAL ENERGY COST	$/MWH	0.00	0.00	0.00
25	25=25	TOTAL ANNUAL COST	$/YR	0.00	0.00	0.00
26	26=22-25	TOTAL ANNUAL NET BENEFIT	$/YR	0.00	0.00	0.00
27	27=22/25	BENEFIT/COST RATIO		0.00	0.00	0.00

AVERAGE INFLOW AT THE RESERVOIR SITE	CFS/CMS	1211.44	0.00
AVERAGE OUTFLOW AT THE RESERVOIR SITE USED FOR GENERATION	CFS/CMS	1200.70	0.00
DESIGN FLOW FOR THE INSTALLED UNIT(S)	CFS/CMS	7710.00	0.00
DESIGN HEAD CALCULATED FROM INSTALLED CAPACITY AND DESIGN FLOW	FT/MT	178.26	0.00
AVERAGE EFFICIENCY BASED ON INFLOW USED FOR GENERATION		0.86	0.00
AVERAGE NET HEAD BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	175.96	0.00
AVERAGE HEADWATER ELEVATION BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	577.50	0.00
AVERAGE TAILWATER ELEVATION BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	401.54	0.00

2. TEST 2 - FEASIBILITY ASSESSMENT OF INSTALLING HYDROPOWER AT EXISTING STORAGE PROJECT.

This test problem assesses the potential maximum hydropower capacity at an existing storage project which presently has no generating facilities. The optimization capability of the program is used in this analysis.

The ananlysis uses an input flow-duration curve (FD Card). The maximum penstock discharge capacity PD.1 was left blank since the maximum installed capacity (OC.1) was to be determined, CAPDES (PD.4 = blank). The design plant efficiency (PD.2) was input as .86, overload factor (PD.5) as 1.2, the annual plant factor (UAPF) as .137, and the power storage adjustment factor (PD.7) as .49. Two units were assumed to be installed (PD.8). The flow diversion (PQ.3) of 47.35 cfs was assumed, with 50 cfs estimated to lost (PD.4) due to leakage and a fish ladder operation. Tailwater fluctuation affects on head were defined by TQ, TH, and TW cards.

The results indicate a maximum installed capacity of 31,947 KW yielding an average annual energy of 123,345 MWH. The natural and adjusted flow duration curves are defined in the output, which is included, along with the input on the following pages.

FLOW DURATION INPUT

```
LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1         T1                                  TEST 2
  2         T2             ANALYSIS OF POTENTIAL HYDROPOWER STORAGE PROJECT
  3         T3                DURATION CURVE ADJUSTED FOR STORAGE AFFECTS
  4         T4           CAPACITIES CALCULATED FOR SPECIFIED FREQUENCIES
  5         FD     CARD    ;STD
  6                .976    1.00    .974    1.26    .974    1.58    .967    2.00    .963    2.51
  7                .961    3.16    .958    3.98    .952    5.01    .947    6.31    .941    7.94
  8                .939    10.0    .934    12.6    .925    15.8    .910    20.0    .888    25.1
  9                .884    31.6    .875    39.8    .849    50.1    .846    63.1    .827    79.4
 10                .785    100.    .770    126.    .761    158.    .719    200.    .691    251.
 11                .651    316.    .618    398.    .575    501.    .535    631.    .487    794.
 12                .421    1000.   .377    1259.   .325    1585.   .243    1995.   .156    2512.
 13                .101    3162.   .057    3981.   .037    5012.   .020    6310.   .007    7943.
 14                .002   10000.   0.     12589.-999.000     0.
 15         PD              .86                     1.2    .137     .49     2.0
 16         PQ                    47.35      50    .958
 17         TQ        0    3000    9000   10500  289000
 18         TH    577.5
 19         TW      400     404     408     440     457
 20         OC       01                             MAX
 21         EJ
```

```
JSTATE ON C2 CARD OMITTED -- COST ANALYSIS INHIBITED
*******************************************************************************
                              TEST 2
           ANALYSIS OF POTENTIAL HYDROPOWER STORAGE PROJECT
              DURATION CURVE ADJUSTED FOR STORAGE AFFECTS
          CAPACITIES CALCULATED FOR SPECIFIED FREQUENCIES
JOB NUMBER     1
*******************************************************************************

IMPLICIT STANDARD UNITS OF MEASUREMENTS

                        LENGTH      POWER      ENERGY    CURRENCY   DISCHARGE        TIME
            ENGLISH     (FOOT)       (KW)       (MWH)    (DOLLAR)       (CFS)        (YR)
             METRIC    (METER)       (KW)       (MWH)    (DOLLAR)       (CMS)        (YR)

AF CARD      SYSTEM         DISPLAY ADJUSTMENT FACTORS APPLIED TO STANDARD UNITS
                          ALEN       APWR       AENRG       ADOLR       AFLOW        TIME
             ENGLSH     1.0000     1.0000      1.0000      1.0000      1.0000      1.0000

FLOW DURATION CURVE INPUT

FD CARD       FTYPE     FMTYPE      PUNCH      ISTATE      IGAUGE
               CARD        STD         NO           0           0

 UNADJUSTED FLOW DURATION CURVE -- FLOWS IN (CFS/CMS) AND EXCEEDENCE PROBABILITIES AS DECIMAL FRACTIONS

PE           0.9760     0.9740     0.9740      0.9670      0.9630      0.9610      0.9580      0.9520      0.9470      0.9410
QQ             1.00       1.26       1.58        2.00        2.51        3.16        3.98        5.01        6.31        7.94

PE           0.9390     0.9340     0.9250      0.9100      0.8880      0.8840      0.8750      0.8490      0.8460      0.8270
QQ            10.00      12.60      15.80       20.00       25.10       31.60       39.80       50.10       63.10       79.40

PE           0.7850     0.7700     0.7610      0.7190      0.6910      0.6510      0.6180      0.5750      0.5350      0.4870
QQ           100.00     126.00     158.00      200.00      251.00      316.00      398.00      501.00      631.00      794.00

PE           0.4210     0.3770     0.3250      0.2430      0.1560      0.1010      0.0570      0.0370      0.0200      0.0070
QQ          1000.00    1259.00    1585.00     1995.00     2512.00     3162.00     3981.00     5012.00     6310.00     7943.00

PE           0.0020     0.0000
QQ         10000.00   12589.00


POWER GENERATION PARAMETERS

PD CARD   MAX PEN Q DESIGN EFF DESIGN HEAD   INST CAP    OVERLOAD  ANN PLANT POWER STORE   NUMBER OF     PEAKING
            CFS/CMS                 FT/MT          KW      FACTOR     FACTOR       RATIO     UNIT(S)      FACTOR
             (QDES)      (EFF)     (HEAD)    (CAPDES)    (OVLOAD)     (UAPF)       (PSR)    (XUNITS)     (PEAKF)
               0.00     0.8600       0.00        0.00       1.200      0.137       0.490       2.000       1.000

PQ CARD SUBMERGENCE   MIN FLOW  DIVERSION     TW LOSS  FLOW RATIO   MIN HEAD    MAX HEAD       SPILL
            CFS/CMS    CFS/CMS    CFS/CMS     CFS/CMS                  FT/MT       FT/MT      EFFECT
             (QSUB)     (QMIN)      (DIV)     (QLOSS)     (QFACT)     (HMIN)      (HMAX)     (SPLEF)
               0.00       0.00      47.35       50.00       0.958       0.00   100000.00         YES

TABLE OF DISCHARGE (CFS/CMS) VS. EFFICIENCY, HEADWATER AND TAILWATER (FT/MT)

TQ CARD        0.00    3000.00    9000.00    10500.00   289000.00  578000.00  1156000.00  2312000.00  4624000.00  9248000.00
TE CARD       0.860      0.860      0.860       0.860       0.860      0.860       0.860       0.860       0.860       0.860
TH CARD      577.50     577.50     577.50      577.50      577.50     577.50      577.50      577.50      577.50      577.50
TW CARD      400.00     404.00     408.00      440.00      457.00     457.00      457.00      457.00      457.00      457.00
```

BENEFIT CALCULATION PARAMETERS

PB CARD	REGION CODE (IREG)	CAP BEN RATIO (CBR)	DEP CAP KW (DCAP)	INPUT AAE MWH (AAEST)	AAE RATIO (RAAE)	STREAMFLOW RELIABILITY (SRP)	ENERGY RATIO (ERATIO)	CAPACITY RATIO (CRATIO)	ENERGY BEN RATIO (SEBR)
	0	0.500	0.00	0.00	1.000	0.850	1.000	1.000	0.500

NO CAPACITY BENEFIT VALUES PROVIDED -- BENEFIT ANALYSIS INHIBITED
ENTER CB CARD OR IREG ON PB CARD

NO ENERGY BENEFIT VALUES PROVIDED -- BENEFIT ANALYSIS INHIBITED
ENTER EB CARD OR IREG ON PB CARD

COST CALCULATION PARAMETERS
($ AMOUNTS X 1000)

C1 CARD	DAM HEIGHT FT/MT (HEIGHT)	DAM LENGTH FT/MT (DIST)	VALLEY SHAPE (KS)	EXIST CAP KW (ECAP)	OPERATION MODE (OPER)	TURBINE (TURB)	RES AREA ACRE/SQ KM (RESA)	WATERWAY L FT/MT (WYL)	WATERWAY Q CFS/CMS (WYQ)	COMPONENT CODE (IPROJ)
	0.00	0.00	1	0.	L	0	0.	0.00	0.00	0
C2 CARD	STATE CODE (JSTATE)	IN/OUTLET K$ (CIO)	POWERHOUSE K$ (CPWH)	EMBANKMENT K$ (CEMB)	SPILLWAY K$ (CSPW)	WATERWAY K$ (CWWY)	RES CLEAR K$ (CRC)	ACQUISITION K$ (CLA)	MISC K$ (CMIS)	COST FACTOR (COSTR)
	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.000
CF CARD	CONTINGENCY FACTOR (CONT)	INTEREST (RATE)	AMORTIZE YEARS (AMOR)	TIME OF CONSTRUCT (PTC)	REPLACE FACTOR (REPL)					
	0.25000	0.06875	100.	5.0	0.01250					

OPTIMIZATION CRITERIA

OC CARD	VARIABLE 1 (IVAR1)	VARIABLE 2 (IVAR2)	COMBINE (ICOMB)	MIN/MAX (OPERND)
	1	0	0	MAX

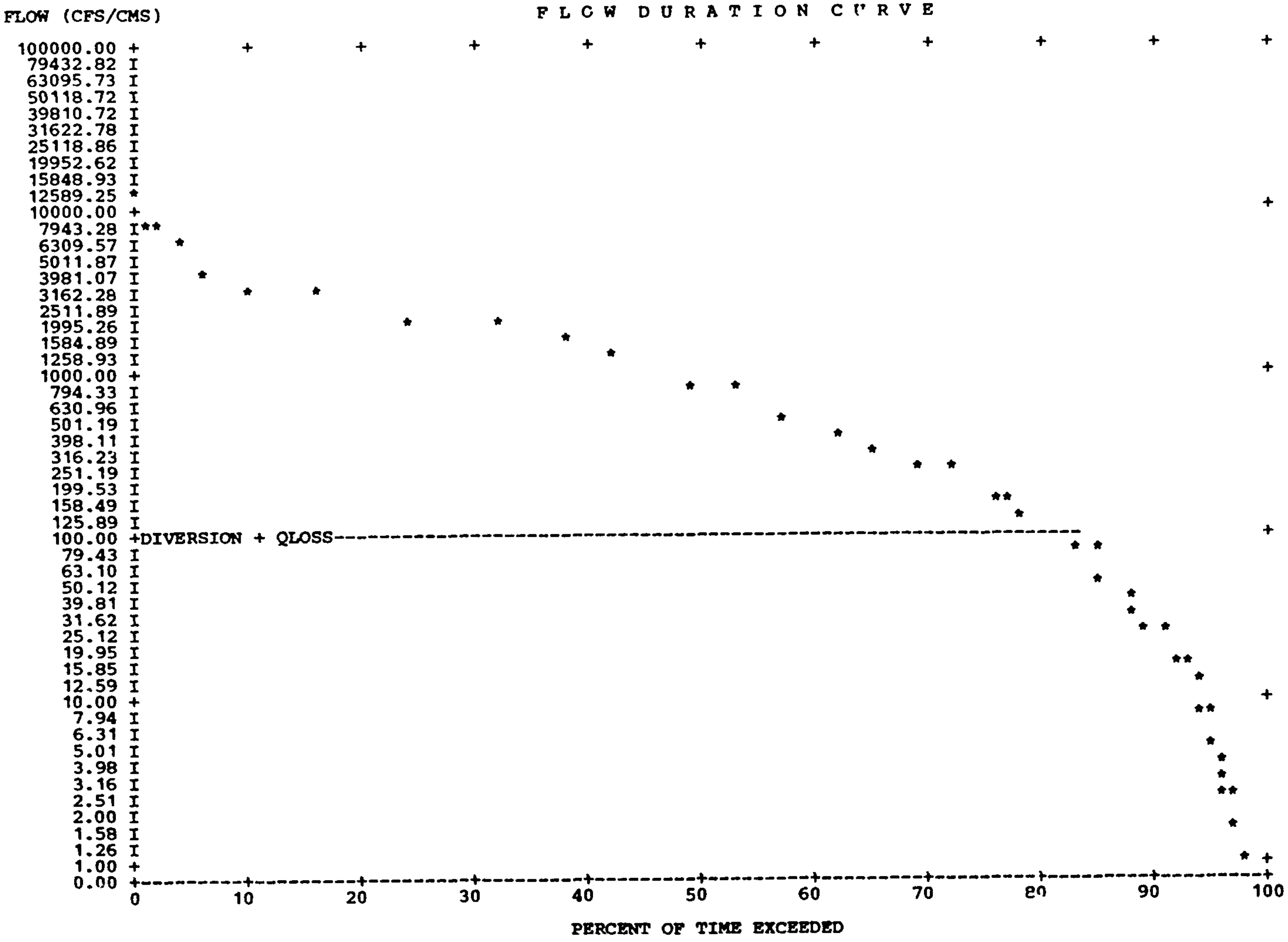
OP CARD PERCENT OF TIME EXCEEDED ORDINATES USED IN OPTIMIZATION TABLE

OP CARD	0.010	0.050	0.100	0.200	0.400	0.600	0.800	0.900	0.950	0.990

PRINT SUPPRESSION

PS CARD	(PLOTS)	(CEFS)	(ECHOS)	(CALCS)	(IPRTS)
	0	0	0	0	0

TEST 2
ANALYSIS OF POTENTIAL HYDROPOWER STORAGE PROJECT
DURATION CURVE ADJUSTED FOR STORAGE AFFECTS
CAPACITIES CALCULATED FOR SPECIFIED FREQUENCIES
JOB NUMBER 1

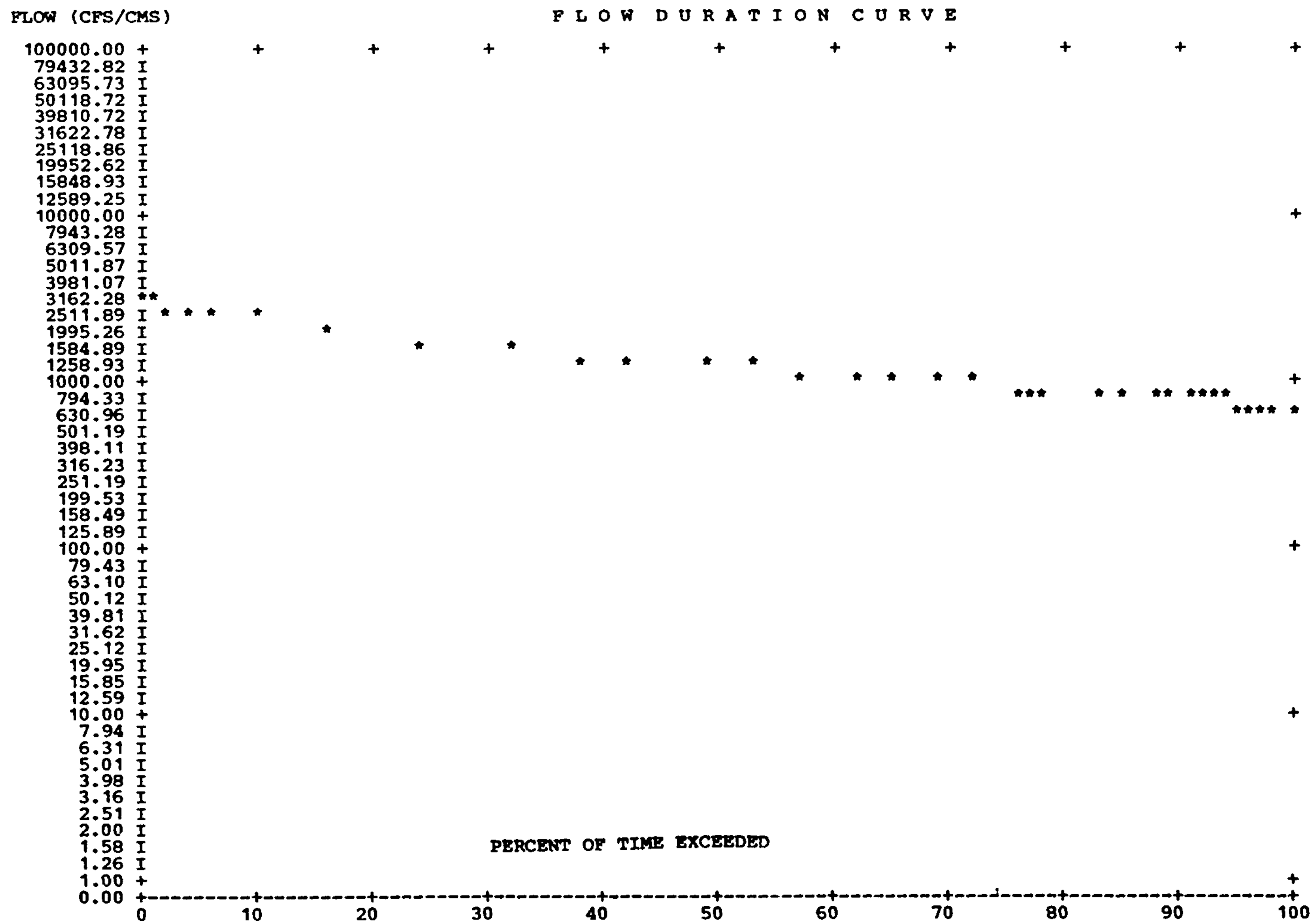


FLOW DURATION CURVE ADJUSTED FOR POWER STORAGE EFFECTS
ADJUSTED FLOW DURATION CURVE -- FLOWS IN CFS/CMS AND PERCENT OF TIME EXCEEDED ORDINATES AS DECIMAL FRACTIONS

XPE	1.0000	0.9760	0.9740	0.9740	0.9670	0.9630	0.9610	0.9580	0.9520	0.9470
XQQ	590.52	606.87	608.25	608.25	613.11	615.91	617.31	619.42	623.66	627.22
XPE	0.9410	0.9390	0.9340	0.9250	0.9100	0.8880	0.8840	0.8750	0.8490	0.8460
XQQ	631.51	632.95	636.56	643.11	654.17	670.75	673.81	680.74	701.17	703.57
XPE	0.8270	0.7850	0.7700	0.7610	0.7190	0.6910	0.6510	0.6180	0.5750	0.5350
XQQ	718.94	754.12	767.09	774.98	812.90	839.21	878.27	911.86	957.56	1002.13
XPE	0.4870	0.4210	0.3770	0.3250	0.2430	0.1560	0.1010	0.0570	0.0370	0.0200
XQQ	1058.36	1140.87	1199.42	1323.42	1565.04	1869.80	2092.39	2289.40	2384.98	2469.36
XPE	0.0070	0.0020	0.0000							
XQQ	2535.89	2561.95	2572.45							

FLOW DURATION CURVE ADJUSTED FOR POWER STORAGE EFFECTS
ADJUSTED FLOW DURATION CURVE -- FLOWS IN CFS/CMS AND PERCENT OF TIME EXCEEDED ORDINATES AS DECIMAL FRACTIONS
****

TEST 2
ANALYSIS OF POTENTIAL HYDROPOWER STORAGE PROJECT
DURATION CURVE ADJUSTED FOR STORAGE AFFECTS
CAPACITIES CALCULATED FOR SPECIFIED FREQUENCIES
JOB NUMBER 1
****



TEST 2
ANALYSIS OF POTENTIAL HYDROPOWER STORAGE PROJECT
DURATION CURVE ADJUSTED FOR STORAGE AFFECTS
CAPACITIES CALCULATED FOR SPECIFIED FREQUENCIES
JOB NUMBER 1

OPTIMIZATION CALCULATIONS
ARRAY OF STORED RESULTS USED TO SELECT CAPACITY
OPTIMIZATION BASED ON ITEMS 1 0

ITEM		PERCENT OF TIME EXCEEDED ORDINATES 1.00	5.00	10.00	20.00	40.00	60.00	80.00	90.00	95.00	99.00
1	CAPDES	31302.	28841.	26018.	21234.	14322.	11298.	8881.	7861.	7392.	7037.
2	AAE	123403.	123620.	123894.	121707.	108111.	97774.	85242.	78288.	74724.	71929.
3	APF	0.45	0.49	0.54	0.65	0.86	0.99	1.10	1.14	1.15	1.17
4	DC	27560.	25431.	22991.	18859.	12894.	10286.	8203.	7255.	6786.	6430.
5	AFE	33075.	30521.	27592.	22633.	15474.	12344.	9845.	8707.	8144.	7717.
6	IC	3742.	3410.	3027.	2376.	1429.	1012.	678.	606.	606.	606.
7	ASE	90328.	93099.	96302.	99074.	92637.	85429.	75398.	69581.	66581.	64212.
8	EQF	33075.	30521.	27592.	22633.	15474.	12344.	9845.	8707.	8144.	7717.
15	AELQ	0.	0.	47.	3103.	17534.	28572.	41881.	49099.	52766.	55686.
16	AELC	0.	0.	45.	3044.	17338.	28322.	41595.	48808.	52471.	55390.
17	CB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	ICB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	EB	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	ACB	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	AEB	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	TAB	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	ICC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	AAEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	TAC	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
26	TANB	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	BCR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ITEMS 2-27 ARE CALCULATED FOR THE INSTALLED CAPACITY AS SHOWN IN ITEM 1. THE INSTALLED CAPACITY WAS CALCULATED USING THE DISCHARGE ON THE FLOW DURATION CURVE ASSOCIATED WITH THE NOTED PERCENT OF TIME EXCEEDED ORDINATE.

	1.00	5.00	10.00	20.00	40.00	60.00	80.00	90.00	95.00	99.00
AVG INFLOW	1211.	1211.	1211.	1211.	1211.	1211.	1211.	1211.	1211.	1211.
AVG GEN Q	1162.67	1162.67	1162.23	1134.14	1001.31	899.44	776.13	709.01	674.85	647.61
DESIGN Q	2520.53	2322.85	2096.88	1715.72	1168.81	930.99	741.55	661.71	625.08	597.33
DES HEAD	170.68	170.65	170.54	170.10	168.41	166.79	164.61	163.27	162.53	161.91
AVG EFF	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
AVG HEAD	173.66	173.96	174.31	174.85	175.50	175.72	175.84	175.87	175.87	175.88
AVG HEADW	577.50	577.50	577.50	577.50	577.50	577.50	577.50	577.50	577.50	577.50
AVG TAILW	403.84	403.54	403.19	402.65	402.00	401.78	401.66	401.63	401.63	401.62

OPTIMUM PERCENT EXCEEDENCE = 0.000

NOTE - FOR EXISTING INSTALLED CAPACITY --
ITEMS 1-27 ARE INCREMENTAL POTENTIAL VALUES
ITEMS 17,18,19,23,24,26 AND 27 ARE RECOMPUTED FROM THE OTHER ITEMS IN THE TABLE

TEST 2
ANALYSIS OF POTENTIAL HYDROPOWER STORAGE PROJECT
DURATION CURVE ADJUSTED FOR STORAGE AFFECTS
CAPACITIES CALCULATED FOR SPECIFIED FREQUENCIES
JOB NUMBER 1

POWER POTENTIAL RESULTS USING FLOW DURATION TECHNIQUE

2 AUG 82

ITEM NUMBER	MATHEMATICAL EXPRESSION	ITEM DESCRIPTION		POTENTIAL CAPACITY	EXISTING CAPACITY	INCREMENTAL CAPACITY
1	1=1	INSTALLED CAPACITY	KW	31947.05	0.00	31947.05
2	2=2	AVERAGE ANNUAL ENERGY	MWH	123345.64	0.00	123345.64
3	3=2/(8.76*1)	AVERAGE ANNUAL PLANT FACTOR		0.44	0.00	0.44
4	4=F(SRP)	DEPENDABLE CAPACITY	KW	28117.89	0.00	28117.89
5	5=5	ANNUAL FIRM ENERGY	MWH	33744.84	0.00	33744.84
6	6=1-4	INTERRUPTIBLE CAPACITY	KW	3829.16	0.00	3829.16
7	7=2-5	ANNUAL SECONDARY ENERGY	KW	89600.79	0.00	89600.79
8	8=5+F(7)	ANNUAL EQUIVALENT FIRM ENERGY	MWH	33744.84	0.00	33744.84
15	15=15	AVERAGE ANNUAL ENERGY LOST DUE TO INSUFFICIENT PENSTOCK CAPACITY	MWH	0.00	0.00	0.00
16	16=16	AVERAGE ANNUAL ENERGY LOST DUE TO INSUFFICIENT GENERAGING CAPACITY	MWH	0.00	0.00	0.00
17	17=17	DEPENDABLE CAPACITY BENEFIT	$/KW-YR	0.00	0.00	0.00
18	18=CBR*17	INTERRUPTIBLE CAPACITY BENEFIT	$/KW-YR	0.00	0.00	0.00
19	19=19	AVERAGE ANNUAL ENERGY BENEFIT	$/MWH	0.00	0.00	0.00
20	20=4*17 + 6*18	ANNUAL CAPACITY BENEFIT	$/YR	0.00	0.00	0.00
21	21=5*19 + 7*F(19)	ANNUAL ENERGY BENEFIT	$/YR	0.00	0.00	0.00
21	21=8*19 (IF 8¢0)					
22	22=20+21	TOTAL ANNUAL BENEFIT	$/YR	0.00	0.00	0.00
23	23=25/1	INSTALLED CAPACITY COST	$/KW-YR	0.00	0.00	0.00
24	24=25/2	AVERAGE ANNUAL ENERGY COST	$/MWH	0.00	0.00	0.00
25	25=25	TOTAL ANNUAL COST	$/YR	0.00	0.00	0.00
26	26=22-25	TOTAL ANNUAL NET BENEFIT	$/YR	0.00	0.00	0.00
27	27=22/25	BENEFIT/COST RATIO		0.00	0.00	0.00

		POTENTIAL CAPACITY	EXISTING CAPACITY
AVERAGE INFLOW AT THE RESERVOIR SITE	CFS/CMS	1211.44	0.00
AVERAGE OUTFLOW AT THE RESERVOIR SITE USED FOR GENERATION	CFS/CMS	1162.67	0.00
DESIGN FLOW FOR THE INSTALLED UNIT(S)	CFS/CMS	2572.45	0.00
DESIGN HEAD CALCULATED FROM INSTALLED CAPACITY AND DESIGN FLOW	FT/MT	170.69	0.00
AVERAGE EFFICIENCY BASED ON INFLOW USED FOR GENERATION		0.86	0.00
AVERAGE NET HEAD BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	173.58	0.00
AVERAGE HEADWATER ELEVATION BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	577.50	0.00
AVERAGE TAILWATER ELEVATION BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	403.92	0.00

3. TEST PROBLEM 3 - ECONOMIC FEASIBILITY OF ADDING POWER TO MONTECELLO DAM

This test problem evaluates the economic feasibility of adding hydroelectric power to an existing project which has no present generating capacity. The objective is to determine automatically (using the optimization capability of the program) the total potential capacity which minimizes the cost of producing energy expressed in terms of dollars per megawatt hours (MWH).

The major input specifications for the problem include: the flow duration relationship, power facility design and flow information, tailwater specifications, and optimization-criteria. The site has a maximum penstock discharge capacity of 1124 cfs (PD.1), an upstream diversion of 99.4 cfs (PQ.3), and a minimum flow for power operation of 75 cfs (PQ.2). An average head of 400 feet is specified in field PD.3, with the tailwater - discharge relationship provided on the TQ and TW cards. Headwater elevations are determined by the program by adding 400 feet (PD.3) to the TW card values instead of inputting headwater elevations on the TH card. Thirteen years of monthly streamflow data developed at the site (PQ.5 = 1.0) and input in a user-supplied format of 10F8.0 (FM.3, FM.4-10) are provided. The FERC regionalized benefits are overriden by user-supplied benefits provided on the EB and CB cards. All costs of the existing project are surpressed except for the cost of the powerhouse (C1.10).

The optimization criteria specified was to minimize the cost of producing energy (OC.1 = 24 and OC.4 = MIN). A 22.2 percent time of exceeded flow values satisfies this objective with an average annual energy cost of $21.01 per MWH. The determined capacity to be installed is 13,939 KW which is capable of generating 60,754 MWH of energy annually. Note that the default option of maximizing net benefits would have altered the installed capacity selected.

The input and output for Test 3 are shown on the following pages.

FLOW DURATION INPUT

```
LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1         T1                           TEST 3
  2         T2                           MONTECELLO DAM
  3         T3                     POWER ANALYSIS AT AN EXISTING DAM
  4         T4          MONTHLY FLOWS IN USER FORMAT, USGS GAGE 11454000, 1959-1971
  5         FD     CARD    USER
  6         FM                     5(10F8.0)
  7                 100     9.0   98.73   11.59   97.47   14.85   94.94   18.95   93.67   24.12
  8               92.41   30.62   89.87   38.81   85.65   49.12   77.22   62.10   69.20   78.43
  9               66.67   99.00   64.14  124.89   61.60  157.49   58.23  198.53   56.54  250.19
 10               53.16  315.23   45.57  397.11   32.07  500.19   15.61  629.96    6.75  793.33
 11                5.49  999.00    4.64 1257.93    0.42 3980.07    -999    -999
 12         PD     1124             400
 13         PQ               75    99.4
 14         TQ        0    1000    3000   10000   20000   40000   50000
 15         TW      190     191     193     200     204     209     211
 16         CB       83      83      83      83      83      83      83      83      83      83
 17         CB       83
 18         EB       44      44      44      44      44      44      44      44      44      44
 19         EB       44
 20         C1        0       0       0       0                                              31
 21         C2        6
 22         CF     0.20    0.09      40
 23         OC       24                     MIN
 24         OP
 25         PS
 26         EJ
```

```
UNRECOGNIZED VALUE FOR OPER ON C1 CARD -- L ASSUMED

UNRECOGNIZED VALUE FOR TURB ON C1 CARD -- 0 ASSUMED
*****************************************************************************
                                TEST 3
                                MONTECELLO DAM
                         POWER ANALYSIS AT AN EXISTING DAM
          MONTHLY FLOWS IN USER FORMAT, USGS GAGE 11454000, 1959-1971
JOB NUMBER     1
*****************************************************************************

IMPLICIT STANDARD UNITS OF MEASUREMENTS

                        LENGTH      POWER      ENERGY     CURRENCY   DISCHARGE        TIME
            ENGLISH     (FOOT)       (KW)      (MWH)      (DOLLAR)     (CFS)          (YR)
             METRIC    (METER)       (KW)      (MWH)      (DOLLAR)     (CMS)          (YR)


AF CARD     SYSTEM          DISPLAY ADJUSTMENT FACTORS APPLIED TO STANDARD UNITS
                          ALEN       APWR       AENRG      ADOLR      AFLOW          TIME
            ENGLSH      1.0000     1.0000     1.0000     1.0000     1.0000         1.0000

FLOW DURATION CURVE INPUT

FD CARD      FTYPE      FMTYPE      PUNCH      ISTATE     IGAUGE
              CARD        USER         NO          0          0

FM CARD       TERM      ITVALS      NVALS
           -999.00     1000000          5

USER FORMAT (9X,10F8.0)

 UNADJUSTED FLOW DURATION CURVE -- FLOWS IN (CFS/CMS) AND EXCEEDENCE PROBABILITIES AS DECIMAL FRACTIONS

PE          1.0000      0.9873     0.9747     0.9494     0.9367     0.9241     0.8987     0.8565     0.7722     0.6920
QQ            9.00       11.59      14.85      18.95      24.12      30.62      38.81      49.12      62.10      78.43

PE          0.6667      0.6414     0.6160     0.5823     0.5654     0.5316     0.4557     0.3207     0.1561     0.0675
QQ           99.00      124.89     157.49     198.53     250.19     315.23     397.11     500.19     629.96     793.33

PE          0.0549      0.0464     0.0042
QQ          999.00     1257.93    3980.07


POWER GENERATION PARAMETERS

PD CARD   MAX PEN Q  DESIGN EFF DESIGN HEAD   INST CAP   OVERLOAD  ANN PLANT POWER STORE  NUMBER OF    PEAKING
            CFS/CMS                  FT/MT        KW      FACTOR     FACTOR       RATIO     UNIT(S)      FACTOR
             (QDES)       (EFF)     (HEAD)    (CAPDES)   (OVLOAD)    (UAPF)       (PSR)    (XUNITS)     (PEAKF)
            1124.00      0.8600     400.00       0.00      1.150      1.000       0.000      0.000        1.000

PQ CARD SUBMERGENCE    MIN FLOW  DIVERSION    TW LOSS  FLOW RATIO  MIN HEAD    MAX HEAD      SPILL
            CFS/CMS     CFS/CMS    CFS/CMS    CFS/CMS               FT/MT       FT/MT       EFFECT
             (QSUB)      (QMIN)      (DIV)    (QLOSS)    (QFACT)    (HMIN)      (HMAX)     (SPLEF)
               0.00       75.00      99.40       0.00      1.000      0.00   100000.00        YES

TABLE OF DISCHARGE (CFS/CMS) VS. EFFICIENCY, HEADWATER AND TAILWATER (FT/MT)

TQ CARD        0.00     1000.00    3000.00   10000.00   20000.00   40000.00   50000.00  100000.00  200000.00  400000.00
TE CARD       0.860       0.860      0.860      0.860      0.860      0.860      0.860      0.860      0.860      0.860
TH CARD      590.00      591.00     593.00     600.00     604.00     609.00     611.00     611.00     611.00     611.00
TW CARD      190.00      191.00     193.00     200.00     204.00     209.00     211.00     211.00     211.00     211.00
```

BENEFIT CALCULATION PARAMETERS

PB CARD	REGION CODE (IREG)	CAP BEN RATIO (CBR)	DEP CAP KW (DCAP)	INPUT AAE MWH (AAEST)	AAE RATIO (RAAE)	STREAMFLOW RELIABILITY (SRP)	ENERGY RATIO (ERATIO)	CAPACITY RATIO (CRATIO)	ENERGY BEN RATIO (SEBR)
	0	0.500	0.00	0.00	1.000	0.850	1.000	1.000	0.500

TABLE OF ANNUAL PLANT FACTOR VS. CAPACITY AND ENERGY BENEFITS

APF	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
CAP BENEFIT ($/KW)	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00
ENG BENEFIT ($/MWH)	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00

COST CALCULATION PARAMETERS
($ AMOUNTS X 1000)

C1 CARD	DAM HEIGHT FT/MT (HEIGHT)	DAM LENGTH FT/MT (DIST)	VALLEY SHAPE (KS)	EXIST CAP KW (ECAP)	OPERATION MODE (OPER)	TURBINE (TURB)	RES AREA ACRE/SQ KM (RESA)	WATERWAY L FT/MT (WYL)	WATERWAY Q CFS/CMS (WYQ)	COMPONENT CODE (IPROJ)
	0.00	0.00	0	0.	L	0	0.	0.00	0.00	31
C2 CARD	STATE CODE (JSTATE)	IN/OUTLET K$ (CIO)	POWERHOUSE K$ (CPWH)	EMBANKMENT K$ (CEMB)	SPILLWAY K$ (CSPW)	WATERWAY K$ (CWWY)	RES CLEAR K$ (CRC)	ACQUISITION K$ (CLA)	MISC K$ (CMIS)	COST FACTOR (COSTR)
	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.000
CF CARD	CONTINGENCY FACTOR (CONT)	INTEREST (RATE)	AMORTIZE YEARS (AMOR)	TIME OF CONSTRUCT (PTC)	REPLACE FACTOR (REPL)					
	0.20000	0.09000	40.	5.0	0.01250					

OPTIMIZATION CRITERIA

OC CARD	VARIABLE 1 (IVAR1)	VARIABLE 2 (IVAR2)	COMBINE (ICOMB)	MIN/MAX (OPERND)
	24	0	0	MIN

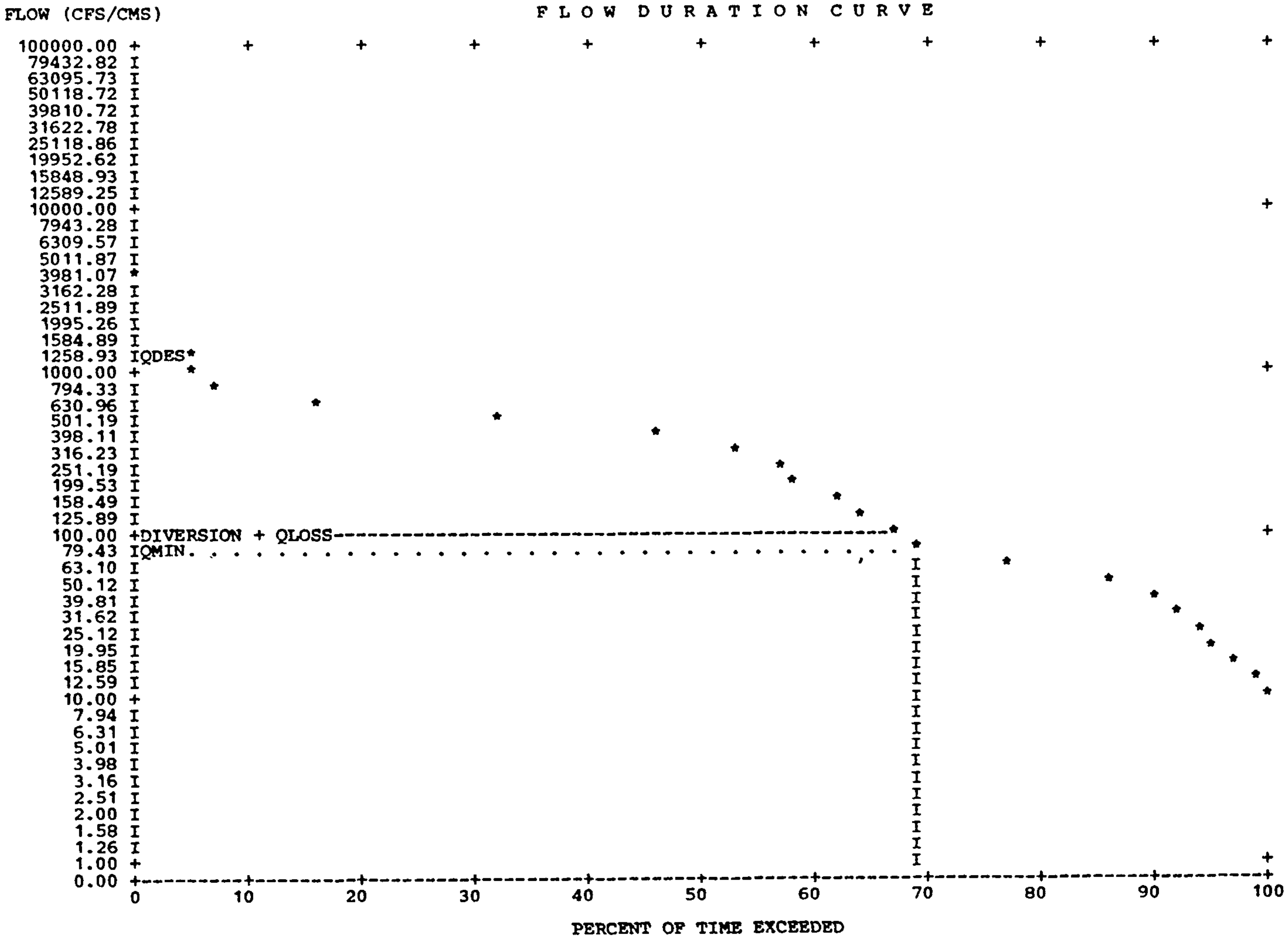
OP CARD PERCENT OF TIME EXCEEDED ORDINATES USED IN OPTIMIZATION TABLE

0.010	0.050	0.100	0.200	0.400	0.600	0.800	0.900	0.950	0.990

PRINT SUPPRESSION

PS CARD	(PLOTS)	(CEFS)	(ECHOS)	(CALCS)	(IPRTS)
	0	0	0	0	0

TEST 3
MONTECELLO DAM
POWER ANALYSIS AT AN EXISTING DAM
MONTHLY FLOWS IN USER FORMAT, USGS GAGE 11454000, 1959-1971
JOB NUMBER 1



ADJUSTED FLOW DURATION CURVE -- FLOWS IN CFS/CMS AND PERCENT OF TIME EXCEEDED ORDINATES AS DECIMAL FRACTIONS

XPE	1.0000	1.0000	0.9873	0.9747	0.9494	0.9367	0.9241	0.8987	0.8565	0.7722
XQQ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XPE	0.6920	0.6667	0.6414	0.6160	0.5823	0.5654	0.5316	0.4557	0.3207	0.1561
XQQ	0.00	0.00	25.49	58.09	99.13	150.79	215.83	297.71	400.79	530.56
XPE	0.0675	0.0549	0.0464	0.0042	0.0000					
XQQ	693.93	899.60	1158.53	3880.67	3880.67					

TEST 3
MONTECELLO DAM
POWER ANALYSIS AT AN EXISTING DAM
MONTHLY FLOWS IN USER FORMAT, USGS GAGE 11454000, 1959-1971
JOB NUMBER 1

OPTIMIZATION CALCULATIONS
ARRAY OF STORED RESULTS USED TO SELECT CAPACITY
OPTIMIZATION BASED ON ITEMS 24 0

	ITEM	1.00	5.00	10.00	20.00	40.00	60.00	80.00	90.00	95.00	99.00
		PERCENT OF TIME EXCEEDED ORDINATES									
1	CAPDES	32712.	30526.	18452.	14434.	9902.	2258.	0.	0.	0.	0.
2	AAE	72263.	71706.	65395.	61323.	51360.	13627.	0.	0.	0.	0.
3	APF	0.25	0.27	0.40	0.48	0.59	0.65	0.00	0.00	0.00	0.00
4	DC	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	AFE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	IC	32712.	30526.	18452.	14434.	9902.	2258.	0.	0.	0.	0.
7	ASE	72263.	71706.	65395.	61323.	51360.	13627.	0.	0.	0.	0.
8	EQF	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	AELQ	16693.	17251.	23562.	27633.	37596.	75329.	0.	0.	0.	0.
16	AELC	16693.	17251.	23562.	27633.	37596.	75329.	0.	0.	0.	0.
17	CB	83.00	83.00	83.00	83.00	83.00	83.00	0.00	0.00	0.00	0.00
18	ICB	41.50	41.50	41.50	41.50	41.50	41.50	0.00	0.00	0.00	0.00
19	EB	44.00	44.00	44.00	44.00	44.00	44.00	0.00	0.00	0.00	0.00
20	ACB	1357559.	1266812.	765744.	599004.	410939.	93694.	0.	0.	0.	0.
21	AEB	1589788.	1577527.	1438681.	1349109.	1129927.	299796.	0.	0.	0.	0.
22	TAB	2947347.	2844339.	2204425.	1948113.	1540867.	393490.	0.	0.	0.	0.
23	ICC	78.64	82.15	76.79	89.56	115.21	142.10	0.00	0.00	0.00	0.00
24	AAEC	35.60	34.97	21.67	21.08	22.21	23.54	0.00	0.00	0.00	0.00
25	TAC	2572400.	2507770.	1416983.	1292745.	1140808.	320813.	0.	0.	0.	0.
26	TANB	374947.	336569.	787442.	655368.	400059.	72677.	0.	0.	0.	0.
27	BCR	1.15	1.13	1.56	1.51	1.35	1.23	0.00	0.00	0.00	0.00

ITEMS 2-27 ARE CALCULATED FOR THE INSTALLED CAPACITY AS SHOWN IN ITEM 1. THE INSTALLED CAPACITY WAS CALCULATED USING THE DISCHARGE ON THE FLOW DURATION CURVE ASSOCIATED WITH THE NOTED PERCENT OF TIME EXCEEDED ORDINATE.

ITEM	1.00	5.00	10.00	20.00	40.00	60.00	80.00	90.00	95.00	99.00
AVG INFLOW	351.	351.	351.	351.	351.	351.	0.	0.	0.	0.
AVG GEN Q	283.44	281.26	256.50	240.53	201.46	53.45	0.00	0.00	0.00	0.00
DESIGN Q	1124.00	1048.87	634.00	495.95	340.24	77.57	0.00	0.00	0.00	0.00
DES HEAD	400.00	400.00	400.00	400.00	400.00	400.00	0.00	0.00	0.00	0.00
AVG EFF	0.86	0.86	0.86	0.86	0.86	0.86	0.00	0.00	0.00	0.00
AVG HEAD	400.00	400.00	400.00	400.00	400.00	400.00	0.00	0.00	0.00	0.00
AVG HEADW	590.35	590.35	590.35	590.35	590.35	590.35	0.00	0.00	0.00	0.00
AVG TAILW	190.35	190.35	190.35	190.35	190.35	190.35	0.00	0.00	0.00	0.00

OPTIMUM PERCENT EXCEEDENCE = 22.200

NOTE - FOR EXISTING INSTALLED CAPACITY --
ITEMS 1-27 ARE INCREMENTAL POTENTIAL VALUES
ITEMS 17,18,19,23,24,26 AND 27 ARE RECOMPUTED FROM THE OTHER ITEMS IN THE TABLE

EXTRAPOLATION OF COST DATA REQUIRED

INTAKE/OUTLET COSTS INHIBITED DUE TO CAPACITY LT 25,000

TEST 3
MONTECELLO DAM
POWER ANALYSIS AT AN EXISTING DAM
MONTHLY FLOWS IN USER FORMAT, USGS GAGE 11454000, 1959-1971
JOB NUMBER 1

COST ESTIMATE FORM
TOTAL POTENTIAL CAPACITY
($1,000,000)
JULY 1978 PRICE LEVEL

	MAJOR COST ITEMS	FIRST COST	TOTAL COST
(1)	POWERPLANT (1 13929.0 KW FRANCIS UNIT)	$ 5.71	
(2)	EMBANKMENT (DAMS, DIKES)	0.00	
(3)	SPILLWAY	0.00	
(4)	INTAKE AND OUTLET WORKS	0.00	
(5)	WATERWAY (CANAL, CHANNEL, CONDUIT)	0.00	
(6)	RESERVOIR CLEARING	0.00	
	INVESTMENT COST COMPUTATIONS		
(7)	TOTAL FIRST COST (SUM OF ITEMS 1-6)	$ 5.71	
(8)	GEOGRAPHIC ADJUSTMENT (1.10 X ITEM 7)	$ 6.29	
(9)	LAND ACQUISITION COST	0.00	
(10)	SUBTOTAL = CONTINGENCY(1.20) X (ITEM 8 + ITEM 9)		$ 7.54
(11)	SPECIAL ITEM COSTS		0.00
(12)	TOTAL CONSTRUCTION COST (ITEM 10 + ITEM 11)		$ 7.54
(13)	ENGINEERING AND OVERHEAD COST (0.175 X ITEM 12)		1.32
(14)	TOTAL PROJECT COST (ITEM 12 + ITEM 13)		$ 8.86
(15)	INTEREST DURING CONSTRUCTION (0.2250 X ITEM 14)		1.99
(16)	TOTAL INVESTMENT COST (ITEM 14 + ITEM 15)		$ 10.86
	ANNUAL COST COMPUTATIONS		
(17)	AMORTIZED COST (0.09296 X ITEM 16)		$ 1.01
(18)	OPERATION AND MAINTENANCE		0.17
(19)	REPLACEMENT COST (1.10 X 1.20 X 0.0125 X ITEM 1)		0.09
(20)	TOTAL ANNUAL COST (ITEM 17 + ITEM 18 + ITEM 19)		$ 1.28
	TOTAL ANNUAL COST X ADJUSTMENT FACTOR COSTR (1.000)		$ 1.28

TEST 3
MONTECELLO DAM
POWER ANALYSIS AT AN EXISTING DAM
MONTHLY FLOWS IN USER FORMAT, USGS GAGE 11454000, 1959-1971
JOB NUMBER 1

POWER POTENTIAL RESULTS USING FLOW DURATION TECHNIQUE 30 JUL 82

ITEM NUMBER	MATHEMATICAL EXPRESSION	ITEM DESCRIPTION		POTENTIAL CAPACITY	EXISTING CAPACITY	INCREMENTAL CAPACITY
1	1=1	INSTALLED CAPACITY	KW	13929.02	0.00	13929.02
2	2=2	AVERAGE ANNUAL ENERGY	MWH	60754.58	0.00	60754.58
3	3=2/(8.76*1)	AVERAGE ANNUAL PLANT FACTOR		0.50	0.00	0.50
4	4=F(SRP)	DEPENDABLE CAPACITY	KW	0.00	0.00	0.00
5	5=5	ANNUAL FIRM ENERGY	MWH	.00	0.00	0.00
6	6=1-4	INTERRUPTIBLE CAPACITY	KW	13929.02	0.00	13929.02
7	7=2-5	ANNUAL SECONDARY ENERGY	KW	60754.58	0.00	60754.58
8	8=5+F(7)	ANNUAL EQUIVALENT FIRM ENERGY	MWH	0.00	0.00	0.00
15	15=15	AVERAGE ANNUAL ENERGY LOST DUE TO INSUFFICIENT PENSTOCK CAPACITY	MWH	28201.93	0.00	28201.93
16	16=16	AVERAGE ANNUAL ENERGY LOST DUE TO INSUFFICIENT GENERAGING CAPACITY	MWH	28201.93	0.00	28201.93
17	17=17	DEPENDABLE CAPACITY BENEFIT	$/KW-YR	83.00	0.00	83.00
18	18=CBR*17	INTERRUPTIBLE CAPACITY BENEFIT	$/KW-YR	41.50	0.00	41.50
19	19=19	AVERAGE ANNUAL ENERGY BENEFIT	$/MWH	44.00	0.00	44.00
20	20=4*17 + 6*18	ANNUAL CAPACITY BENEFIT	$/YR	578054.41	0.00	578054.41
21	21=5*19 + 7*F(19)	ANNUAL ENERGY BENEFIT	$/YR	1336600.86	0.00	1336600.86
21	21=8*19 (IF 8¢0)					
22	22=20+21	TOTAL ANNUAL BENEFIT	$/YR	1914655.27	0.00	1914655.27
23	23=25/1	INSTALLED CAPACITY COST	$/KW-YR	91.65	0.00	91.65
24	24=25/2	AVERAGE ANNUAL ENERGY COST	$/MWH	21.01	0.00	21.01
25	25=25	TOTAL ANNUAL COST	$/YR	1276614.95	0.00	1276614.95
26	26=22-25	TOTAL ANNUAL NET BENEFIT	$/YR	638040.32	0.00	638040.32
27	27=22/25	BENEFIT/COST RATIO		1.50	0.00	1.50

AVERAGE INFLOW AT THE RESERVOIR SITE	CFS/CMS	351.29	0.00
AVERAGE OUTFLOW AT THE RESERVOIR SITE USED FOR GENERATION	CFS/CMS	238.30	0.00
DESIGN FLOW FOR THE INSTALLED UNIT(S)	CFS/CMS	1124.00	0.00
DESIGN HEAD CALCULATED FROM INSTALLED CAPACITY AND DESIGN FLOW	FT/MT	170.32	0.00
AVERAGE EFFICIENCY BASED ON INFLOW USED FOR GENERATION		0.86	0.00
AVERAGE NET HEAD BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	400.00	0.00
AVERAGE HEADWATER ELEVATION BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	590.35	0.00
AVERAGE TAILWATER ELEVATION BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	190.35	0.00

4. TEST PROBLEM 4 - THE DALLES RUN-OF-RIVER PROJECT

This test problem analyzes the economic feasibility of adding capacity to an existing 1,806,800 KW (C1.4) run-of-river project (PD.7=0). Both the penstock capacity and the plant capacity are to be optimized so the PD.1 and PD.4 fields are left blank. A negative net evaporation of -12 cfs (precipitation gain) is entered in field PQ.3. The net power head versus discharge relationship is provided on the TH and TQ cards. Since power head and not headwater elevations were use on the TH cards, tailwater elevations of zero must be entered on the TW card. An annual plant factor for firm energy delivery is assumed to be 1.0 (PD.6).

The streamflow-duration curve, developed from streamflows at site (PQ.5=1.0) is entered via cards (FD.1=CARD) in standard format (FD.2=STD). Default energy and capacity benefits for the FERC region code 17 (PB.1) are used. Costs are based on information provided on the C1 and C2 cards using the North Pacific Division, (NPD) Corps of Engineers, cost estimating procedures. The calculated total annual cost is adjusted by 1.3 (C2.10). The OP card specifies that the optimization summarizes tables for the 5, 5.5, 6, 8. 10, 12, 14, 16, 18, and 20 percent of time ordinates (existing capacity corresponds to approximately 20 percent time of exceeded ordinate). The PS card suppresses all plots (PS.1) and the tabulation of the streamflow-duration curve (PS.4).

The optimization table for various percent of time exceeded displays two columns exhibiting a negative incremental capacity (corresponding to 18 and 20 percent exceedence). The total annual cost, 9999999999, is used by the cost estimating routines whenever an estimate of powerhouse costs is not possible. The two parameters needed for this cost component estimate are the unit capacity and corresponding design head. (Refer to the NPD cost estimating manual for examples of powerhouse cost curves).

The additional installed capacity determined from the optimization analysis is 144,061 KW which corresponds to an exceedence value of 14.3 percent of the time. The total capacity of the facility would be 1,950,861 KW. The incremental additional capacity is economically feasible to install assuming given benefits and costs.

The input and output for Test 4 are shown on the following pages.

FLOW DURATION INPUT

```
LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1         T1                                 TEST 4
  2         T2                                     THE DALLES
  3         T3                 POWER ANALYSIS AT AN EXISTING RUN OF RIVER PROJECT
  4         T4    FLOW DURATION CURVE BASED ON DAILY FLOWS FROM USGS GAGE 14105700, 1878-1978
  5         FD      CARD      STD
  6         FM
  7               1.0000  10000.  1.0000  12600.  1.0000  15800.  1.0000  20000.  1.0000  25100.
  8               1.0000  31600.   .9998  39800.   .9966  50100.   .9760  63100.   .8864  79400.
  9                .7340 100000.   .5563 126000.   .4142 158000.   .3130 200000.   .2366 251000.
 10                .1682 316000.   .1084 398000.   .0536 501000.   .0175 631000.   .0030 794000.
 11                .00041000000.  0.    1260000.  0.    1580000.  0.    2000000.  0.    2510000.
 12               0.      3160000.-999.000      0.
 13         PD                                           1       1            20.15
 14         PQ                       -12
 15         TQ          0  150000  300000  400000  500000  600000  700000  800000 1000000
 16         TH       84.8    82.8    78.2    74.7    70.1    60.0    45.1    20.2    0.01
 17         PB         17
 18         C1        185    8735       1 1806800                C   14000                      63
 19         C2         41                                                                      1.3
 20         OP          5     5.5       6       8      10      12      14      16      18      20
 21         PS          7                       1
 22         EJ
```

```
UNRECOGNIZED VALUE FOR OPER ON C1 CARD -- L ASSUMED

UNRECOGNIZED VALUE FOR TURB ON C1 CARD -- 0 ASSUMED
*****************************************************************************
                                        TEST 4
                                      THE DALLES
                    POWER ANALYSIS AT AN EXISTING RUN OF RIVER PROJECT
    FLOW DURATION CURVE BASED ON DAILY FLOWS FROM USGS GAGE 14105700, 1878-1978
JOB NUMBER      1
*****************************************************************************

IMPLICIT STANDARD UNITS OF MEASUREMENTS

                         LENGTH       POWER      ENERGY     CURRENCY    DISCHARGE        TIME
              ENGLISH    (FOOT)        (KW)       (MWH)     (DOLLAR)        (CFS)        (YR)
               METRIC   (METER)        (KW)       (MWH)     (DOLLAR)        (CMS)        (YR)

AF CARD        SYSTEM       DISPLAY ADJUSTMENT FACTORS APPLIED TO STANDARD UNITS
                             ALEN        APWR       AENRG       ADOLR       AFLOW        TIME
               ENGLSH      1.0000      1.0000      1.0000      1.0000      1.0000      1.0000

FLOW DURATION CURVE INPUT

FD CARD         FTYPE      FMTYPE       PUNCH      ISTATE      IGAUGE
                 CARD         STD          NO           0           0

FM CARD          TERM      ITVALS       NVALS
              -999.00     1000000           0

 UNADJUSTED FLOW DURATION CURVE -- FLOWS IN (CFS/CMS) AND EXCEEDENCE PROBABILITIES AS DECIMAL FRACTIONS

PE             1.0000      1.0000      1.0000      1.0000      1.0000      1.0000      0.9998      0.9966      0.9760      0.8864
QQ           10000.00    12600.00    15800.00    20000.00    25100.00    31600.00    39800.00    50100.00    63100.00    79400.00

PE             0.7340      0.5563      0.4142      0.3130      0.2366      0.1682      0.1084      0.0536      0.0175      0.0030
QQ          100000.00   126000.00   158000.00   200000.00   251000.00   316000.00   398000.00   501000.00   631000.00   794000.00

PE             0.0004      0.0000      0.0000      0.0000      0.0000      0.0000
QQ         1000000.00  1260000.00  1580000.00  2000000.00  2510000.00  3160000.00


POWER GENERATION PARAMETERS

PD CARD     MAX PEN Q  DESIGN EFF DESIGN HEAD    INST CAP    OVERLOAD   ANN PLANT POWER STORE   NUMBER OF     PEAKING
              CFS/CMS                   FT/MT          KW      FACTOR      FACTOR       RATIO     UNIT(S)      FACTOR
               (QDES)       (EFF)      (HEAD)    (CAPDES)    (OVLOAD)      (UAPF)       (PSR)    (XUNITS)     (PEAKF)
                 0.00      0.8600        0.00        0.00       1.000       1.000       0.000      20.150       1.000

PQ CARD SUBMERGENCE      MIN FLOW   DIVERSION     TW LOSS  FLOW RATIO    MIN HEAD    MAX HEAD       SPILL
              CFS/CMS     CFS/CMS     CFS/CMS     CFS/CMS                   FT/MT       FT/MT      EFFECT
               (QSUB)      (QMIN)       (DIV)     (QLOSS)     (QFACT)      (HMIN)      (HMAX)     (SPLEF)
                 0.00        0.00      -12.00        0.00       1.000        0.00   100000.00         YES

TABLE OF DISCHARGE (CFS/CMS) VS. EFFICIENCY, HEADWATER AND TAILWATER (FT/MT)

TQ CARD          0.00   150000.00   300000.00   400000.00   500000.00   600000.00   700000.00   800000.00  1000000.00  2000000.00
TE CARD         0.860       0.860       0.860       0.860       0.860       0.860       0.860       0.860       0.860       0.860
TH CARD         84.80       82.80       78.20       74.70       70.10       60.00       45.10       20.[illegible]        0.01        0.01
TW CARD          0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00        0.00
```

BENEFIT CALCULATION PARAMETERS

PB CARD	REGION CODE (IREG)	CAP BEN RATIO (CBR)	DEP CAP KW (DCAP)	INPUT AAE MWH (AAEST)	AAE RATIO (RAAE)	STREAMFLOW RELIABILITY (SRP)	ENERGY RATIO (ERATIO)	CAPACITY RATIO (CRATIO)	ENERGY BEN RATIO (SEBR)
	17	0.500	0.00	0.00	1.000	0.850	1.000	1.000	0.500

TABLE OF ANNUAL PLANT FACTOR VS. CAPACITY AND ENERGY BENEFITS

APF	0.000	0.100	0.200	0.300	0.400	0.500	0.600	0.700	0.800	0.900	1.000
CAP BENEFIT ($/KW)	30.30	24.70	24.70	53.60	53.60	121.00	121.00	121.00	121.00	121.00	121.00
ENG BENEFIT ($/MWH)	31.90	31.90	28.70	21.10	21.20	14.10	13.50	13.10	12.70	12.50	12.30

COST CALCULATION PARAMETERS
($ AMOUNTS X 1000)

C1 CARD	DAM HEIGHT FT/MT (HEIGHT)	DAM LENGTH FT/MT (DIST)	VALLEY SHAPE (KS)	EXIST CAP KW (ECAP)	OPERATION MODE (OPER)	TURBINE (TURB)	RES AREA ACRE/SQ KM (RESA)	WATERWAY L FT/MT (WYL)	WATERWAY Q CFS/CMS (WYQ)	COMPONENT CODE (IPROJ)
	185.00	8735.00	1	1806800.	L	0	14000.	0.00	0.00	63

C2 CARD	STATE CODE (JSTATE)	IN/OUTLET K$ (CIO)	POWERHOUSE K$ (CPWH)	EMBANKMENT K$ (CEMB)	SPILLWAY K$ (CSPW)	WATERWAY K$ (CWWY)	RES CLEAR K$ (CRC)	ACQUISITION K$ (CLA)	MISC K$ (CMIS)	COST FACTOR (COSTR)
	41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.300

CF CARD	CONTINGENCY FACTOR (CONT)	INTEREST (RATE)	AMORTIZE YEARS (AMOR)	TIME OF CONSTRUCT (PTC)	REPLACE FACTOR (REPL)
	0.25000	0.06875	100.	5.0	0.01250

OPTIMIZATION CRITERIA

OC CARD	VARIABLE 1 (IVAR1)	VARIABLE 2 (IVAR2)	COMBINE (ICOMB)	MIN/MAX (OPERND)
	26	0	0	MAX

OP CARD PERCENT OF TIME EXCEEDED ORDINATES USED IN OPTIMIZATION TABLE

0.050	0.055	0.060	0.080	0.100	0.120	0.140	0.160	0.180	0.200

PRINT SUPPRESSION

PS CARD	(PLOTS)	(CEFS)	(ECHOS)	(CALCS)	(IPRTS)
	7	0	0	1	0

TEST 4
THE DALLES
POWER ANALYSIS AT AN EXISTING RUN OF RIVER PROJECT
FLOW DURATION CURVE BASED ON DAILY FLOWS FROM USGS GAGE 14105700, 1878-1978
JOB NUMBER 1

COST ESTIMATE FORM
EXISTING CAPACITY
($1,000,000)
JULY 1978 PRICE LEVEL

	MAJOR COST ITEMS	FIRST COST	TOTAL COST
(1)	POWERPLANT (15 120453.3 KW KAPLAN UNIT)	$ 526.47	
(2)	EMBANKMENT (DAMS, DIKES)	0.00	
(3)	SPILLWAY	0.00	
(4)	INTAKE AND OUTLET WORKS	0.00	
(5)	WATERWAY (CANAL, CHANNEL, CONDUIT)	0.00	
(6)	RESERVOIR CLEARING	0.00	
	INVESTMENT COST COMPUTATIONS		
(7)	TOTAL FIRST COST (SUM OF ITEMS 1-6)	$ 526.47	
(8)	GEOGRAPHIC ADJUSTMENT (1.00 X ITEM 7)	$ 526.47	
(9)	LAND ACQUISITION COST	0.00	
(10)	SUBTOTAL = CONTINGENCY(1.25) X (ITEM 8 + ITEM 9)		$ 658.09
(11)	SPECIAL ITEM COSTS		0.00
(12)	TOTAL CONSTRUCTION COST (ITEM 10 + ITEM 11)		$ 658.09
(13)	ENGINEERING AND OVERHEAD COST (0.095 X ITEM 12)		62.52
(14)	TOTAL PROJECT COST (ITEM 12 + ITEM 13)		$ 720.60
(15)	INTEREST DURING CONSTRUCTION (0.1719 X ITEM 14)		123.85
(16)	TOTAL INVESTMENT COST (ITEM 14 + ITEM 15)		$ 844.46
	ANNUAL COST COMPUTATIONS		
(17)	AMORTIZED COST (0.06884 X ITEM 16)		$ 58.13
(18)	OPERATION AND MAINTENANCE		3.61
(19)	REPLACEMENT COST (1.00 X 1.25 X 0.0125 X ITEM 1)		8.23
(20)	TOTAL ANNUAL COST (ITEM 17 + ITEM 18 + ITEM 19)		$ 69.96
	TOTAL ANNUAL COST X ADJUSTMENT FACTOR COSTR (1.300)		$ 90.95

```
UNIT FACTOR EXTRAPOLATED
UNIT CAPACITY (MW) =       6.63 MIN TABLE CAPACITY (MW) =      10.00
UNIT FACTOR        =       3.29 MIN TABLE FACOTR        =       3.31

UNIT FACTOR EXTRAPOLATED
UNIT CAPACITY (MW) =       6.63 MIN TABLE CAPACITY (MW) =      10.00
UNIT FACTOR        =       3.31 MIN TABLE FACOTR        =       3.31
```

TEST 4
THE DALLES
POWER ANALYSIS AT AN EXISTING RUN OF RIVER PROJECT
FLOW DURATION CURVE BASED ON DAILY FLOWS FROM USGS GAGE 14105700, 1878-1978
JOB NUMBER 1

OPTIMIZATION CALCULATIONS
ARRAY OF STORED RESULTS USED TO SELECT CAPACITY
OPTIMIZATION BASED ON ITEMS 26 0

	ITEM	PERCENT OF TIME EXCEEDED ORDINATES									
		5.00	5.50	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00
1	CAPDES	780260.	780260.	738422.	577292.	426774.	287774.	162615.	33163.	-76140.	-170579.
2	AAE	900578.	900578.	856104.	724641.	561970.	363636.	273457.	57032.	-168534.	-183985.
3	APF	0.13	0.13	0.13	0.14	0.15	0.14	0.19	0.20	0.25	0.12
4	DC	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	AFE	1434.	1434.	1434.	1434.	1434.	1434.	1434.	7045.	24907.	11616.
6	IC	780260.	780260.	738422.	577292.	426774.	287774.	162615.	33163.	-76140.	-170579.
7	ASE	899143.	899143.	854669.	723207.	560536.	362202.	272023.	49986.	-193441.	-195601.
8	EQF	1434.	1434.	1434.	1434.	1434.	1434.	1434.	7045.	24907.	11616.
15	AELQ	-770935.	-770935.	-670595.	-601994.	-547158.	-238010.	-111003.	-22292.	144191.	252610.
16	AELC	-637213.	-637213.	-627123.	-544868.	-468030.	-276417.	-156198.	-31854.	151762.	288433.
17	CB	-123.75	-123.75	-120.94	-98.96	-69.99	-29.10	121.00	121.00	121.00	121.00
18	ICB	-61.87	-61.87	-60.47	-49.48	-34.99	-14.55	60.50	60.50	60.50	60.50
19	EB	114.13	114.13	113.70	102.26	91.35	82.29	21.78	21.07	20.28	32.31
20	ACB	-48278219.	-48278219.	-44653775.	-28565339.	-14934601.	-4187711.	9838228.	2006345.	-4606452.	-10320011.
21	AEB	51475438.	51475438.	48749234.	37123045.	25732484.	15020716.	2993205.	674904.	-1456057.	-2784394.
22	TAB	3197219.	3197219.	4095458.	8557707.	10797883.	10833005.	12831433.	2681248.	-6062509.	-13104404.
23	ICC	16.62	16.62	16.66	16.88	17.43	18.22	19.52	115.62	-131337.53	-58623.97
24	AAEC	14.40	14.40	14.37	13.45	13.23	14.42	11.61	67.23	-59335.35	-54352.39
25	TAC	12967452.	12967452.	12301839.	9744132.	7437216.	5242430.	3175032.	3834219.	9999999999.	9999999999.
26	TANB	-9770233.	-9770233.	-8206381.	-1186426.	3360667.	5590575.	9656401.	-1152971.	***********	***********
27	BCR	0.25	0.25	0.33	0.88	1.45	2.07	4.04	0.70	0.00	0.00

ITEMS 2-27 ARE CALCULATED FOR THE INSTALLED CAPACITY AS SHOWN IN ITEM 1. THE INSTALLED CAPACITY WAS CALCULATED USING THE DISCHARGE ON THE FLOW DURATION CURVE ASSOCIATED WITH THE NOTED PERCENT OF TIME EXCEEDED ORDINATE.

	5.00	5.50	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00
AVG INFLOW	195905.	195905.	195905.	195905.	195905.	195905.	195905.	195905.	195905.	195905.
AVG GEN Q	189672.89	189672.89	189002.04	185193.78	182149.62	178673.93	174875.26	171085.00	167257.68	163411.86
DESIGN Q	514012.51	514012.51	498435.69	451420.19	413837.95	382149.43	354682.57	327276.47	304799.37	285798.25
DES HEAD	69.17	69.17	70.18	72.59	74.18	75.33	76.32	77.27	78.04	78.69
AVG EFF	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
AVG HEAD	79.13	79.13	79.13	79.13	79.13	79.13	79.13	79.13	79.13	79.13
AVG HEADW	79.13	79.13	79.13	79.13	79.13	79.13	79.13	79.13	79.13	79.13
AVG TAILW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

OPTIMUM PERCENT EXCEEDENCE = 14.295

NOTE - FOR EXISTING INSTALLED CAPACITY --
ITEMS 1-27 ARE INCREMENTAL POTENTIAL VALUES
ITEMS 17,18,19,23,24,26 AND 27 ARE RECOMPUTED FROM THE OTHER ITEMS IN THE TABLE

```
********************************************************************************
                              TEST 4
                              THE DALLES
            POWER ANALYSIS AT AN EXISTING RUN OF RIVER PROJECT
   FLOW DURATION CURVE BASED ON DAILY FLOWS FROM USGS GAGE 14105700, 1878-1978
JOB NUMBER    1
********************************************************************************

                           COST ESTIMATE FORM
                        INCRL POTENTIAL CAPACITY
                              ($1,000,000)
                         JULY 1978 PRICE LEVEL

                                                               FIRST          TOTAL
     MAJOR COST ITEMS                                           COST           COST

 (1) POWERPLANT ( 5   28812.2 KW SMALL KAPLAN UNIT)  $        12.96
 (2) EMBANKMENT (DAMS, DIKES)                                  0.00
 (3) SPILLWAY                                                  0.00
 (4) INTAKE AND OUTLET WORKS                                   0.00
 (5) WATERWAY (CANAL, CHANNEL, CONDUIT)                        0.00
 (6) RESERVOIR CLEARING                                        0.00

     INVESTMENT COST COMPUTATIONS
                                                         ----------
 (7) TOTAL FIRST COST (SUM OF ITEMS 1-6)             $        12.96
 (8) GEOGRAPHIC ADJUSTMENT ( 1.00 X ITEM 7)          $        12.96
 (9) LAND ACQUISITION COST                                     0.00

(10) SUBTOTAL = CONTINGENCY( 1.25) X (ITEM 8 + ITEM 9)                 $      16.20
(11) SPECIAL ITEM COSTS                                                        0.00
                                                                         ----------
(12) TOTAL CONSTRUCTION COST (ITEM 10 + ITEM 11)                       $      16.20

(13) ENGINEERING AND OVERHEAD COST (0.175 X ITEM 12)                           2.83
                                                                         ----------
(14) TOTAL PROJECT COST (ITEM 12 + ITEM 13)                            $      19.03

(15) INTEREST DURING CONSTRUCTION ( 0.1719 X ITEM 14)                          3.27
                                                                         ----------
(16) TOTAL INVESTMENT COST (ITEM 14 + ITEM 15)                         $      22.31
                                                                         ==========
     ANNUAL COST COMPUTATIONS

(17) AMORTIZED COST ( 0.06884 X ITEM 16)                               $       1.54
(18) OPERATION AND MAINTENANCE                                                 0.47
(19) REPLACEMENT COST ( 1.00 X  1.25 X 0.0125 X ITEM 1)                        0.20
                                                                         ----------
(20) TOTAL ANNUAL COST (ITEM 17 + ITEM 18 + ITEM 19)                   $       2.21
                                                                         ==========

     TOTAL ANNUAL COST X ADJUSTMENT FACTOR COSTR ( 1.300)              $       2.87
```

TEST 4
THE DALLES
POWER ANALYSIS AT AN EXISTING RUN OF RIVER PROJECT
FLOW DURATION CURVE BASED ON DAILY FLOWS FROM USGS GAGE 14105700, 1878-1978
JOB NUMBER 1

POWER POTENTIAL RESULTS USING FLOW DURATION TECHNIQUE 30 JUL 82

ITEM NUMBER	MATHEMATICAL EXPRESSION	ITEM DESCRIPTION		POTENTIAL CAPACITY	EXISTING CAPACITY	INCREMENTAL CAPACITY
1	1=1	INSTALLED CAPACITY	KW	1950861.03	1806800.00	144061.03
2	2=2	AVERAGE ANNUAL ENERGY	MWH	8628176.58	8359688.26	268488.32
3	3=2/(8.76*1)	AVERAGE ANNUAL PLANT FACTOR		0.50	0.53	0.21
4	4=F(SRP)	DEPENDABLE CAPACITY	KW	513349.46	513349.46	0.00
5	5=5	ANNUAL FIRM ENERGY	MWH	4316214.01	4314779.52	1434.50
6	6=1-4	INTERRUPTIBLE CAPACITY	KW	1437511.57	1293450.54	144061.03
7	7=2-5	ANNUAL SECONDARY ENERGY	KW	4311962.57	4044908.75	267053.82
8	8=5+F(7)	ANNUAL EQUIVALENT FIRM ENERGY	MWH	4316214.01	4314779.52	1434.50
15	15=15	AVERAGE ANNUAL ENERGY LOST DUE TO INSUFFICIENT PENSTOCK CAPACITY	MWH	796440.69	894533.34	-98092.66
16	16=16	AVERAGE ANNUAL ENERGY LOST DUE TO INSUFFICIENT GENERAGING CAPACITY	MWH	498837.02	637212.54	-138375.52
17	17=17	DEPENDABLE CAPACITY BENEFIT	$/KW-YR	121.00	121.00	121.00
18	18=CBR*17	INTERRUPTIBLE CAPACITY BENEFIT	$/KW-YR	60.50	60.50	60.50
19	19=19	AVERAGE ANNUAL ENERGY BENEFIT	$/MWH	14.07	13.93	20.63
20	20=4*17 + 6*18	ANNUAL CAP.CITY BENEFIT	$/YR	149084735.07	140369042.62	8715692.45
21	21=5*19 + 7*F(19)	ANNUAL ENERGY BENEFIT	$/YR	91068428.97	88283778.46	2784650.51
21	21=8*19 (IF 8¢0)					
22	22=20+21	TOTAL ANNUAL BENEFIT	$/YR	240153164.04	22[illegible]652821.09	11500342.95
23	23=25/1	INSTALLED CAPACITY COST	$/KW-YR	48.09	50.34	19.91
24	24=25/2	AVERAGE ANNUAL ENERGY COST	$/MWH	10.87	10.88	10.68
25	25=25	TOTAL ANNUAL COST	$/YR	93822026.59	90954021.49	2868005.10
26	26=22-25	TOTAL ANNUAL NET BENEFIT	$/YR	146331137.45	137698799.60	8632337.85
27	27=22/25	BENEFIT/COST RATIO		2.56	2.51	4.01

		POTENTIAL CAPACITY	EXISTING CAPACITY
AVERAGE INFLOW AT THE RESERVOIR SITE	CFS/CMS	195905.17	195905.17
AVERAGE OUTFLOW AT THE RESERVOIR SITE USED FOR GENERATION	CFS/CMS	174323.67	170132.53
DESIGN FLOW FOR THE INSTALLED UNIT(S)	CFS/CMS	350694.18	320389.53
DESIGN HEAD CALCULATED FROM INSTALLED CAPACITY AND DESIGN FLOW	FT/MT	76.46	77.51
AVERAGE EFFICIENCY BASED ON INFLOW USED FOR GENERATION		0.86	0.86
AVERAGE NET HEAD BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	79.13	79.13
AVERAGE HEADWATER ELEVATION BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	79.13	79.13
AVERAGE TAILWATER ELEVATION BASED ON THE INFLOW AT THE RESERVOIR SITE	FT/MT	0.00	0.00

EXHIBIT 4

DESCRIPTION OF PROGRAM OUTPUT

The output from the program falls into the following categories: (1) banner page; (2) flow-duration input; (3) summary of the input variables and selected job options; (4) a plot of the unadjusted flow-duration curve; (5) ordinates and plot of the adjusted streamflow-duration curve; (6) cost estimate from the existing capacity; (7) plot of the capacity-duration curve for the existing capacity; (8) extrapolation warning messages; (9) summary of optimization calculations; (10) cost estimate form for the total potential capacity; (11) summary of the power analysis for total potential, existing, and incremental capacity; (12) and a plot of the capacity-duration curve for the total potential capacity. A detailed description of the items that appear in the output is given below.

(1) Banner Page. The banner page contains the program title. On the Corps of Engineers library versions at the Lawrence Berkeley Laboratory (LBL) and Boeing Computer System (BCS) a general and HYDUR message are printed. Respectively, these provide general information about the Corps computer library and specific comments about the HYDUR program.

(2) Flow-Duration Input. This page provides a copy of the input cards for the entire run.

(3) Summary of Input Variables and Selected Job Options. All the input variables and selected job options used in the indicated job number are summarized. When several jobs are stacked, this summary will indicate what options are in effect for the current job.

(4) Plot of the Flow-Duration Curve. The unadjusted streamflow duration plot is provided with notes indicating QLOSS, QMIN, and DIV. The streamflows are plotted on a logarithmic scale versus an linear percent of time scale.

(5) Adjusted Flow-Duration Curve Ordinates. The unadjusted streamflow-duration ordinates are multiplied by QFACT and DIV is subtracted yielding the adjusted streamflow ordinates that are printed. If PD.7 is positive the curve is also adjusted for power storage effects (see Exhibit 2).

(6) Cost Estimate Form for Existing Capacity. The cost estimate form for the existing capacity is printed when the value for ECAP is non-zero (C1.4). This form is based on the cost estimating procedures developed by the North Pacific Division (NPD). Warning messages are printed above the form when the cost functions are extrapolated.

(7) Plot of Capacity-Duration Curve for Existing Capacity. A plot of the capacity-duration curve is printed when ECAP is non-zero (C1.4). The capacity values, which are limited to ECAP times the overload, are plotted on a logarithmic scale.

(8) Extrapolation Warning Messages. Warning messages are printed when extrapolation occurs in the cost routines that are called during the construction of the optimization calculations. The program internally cycles 20 times through the optimization table so some messages may be repeated up to 20 times.

(9) Summary of Optimization Table. The optimization table summarizes the thirty items described in Table 2 of the users manual. These items are printed for the capacities corresponding to the percent of time exceeded ordinates requested on the OP card. When ECAP, the existing capacity, is specified (C1.4), all items displayed are incremental values (total potential minus the existing potential values). The lower portion of the table summarizes the average operating characteristics in the power analysis which include the inflow available for generation, the outflow used for power generation, the efficiency, net head, headwater elevation, and tailwater elevation. In addition the design penstock capacity is printed. This value is either the value supplied by the user, or when not supplied it is computed by the program to provide just enough flow to allow generation of the installed capacity. The design head is calculated from the installed capacity and the design flow. At the bottom of the table the optimum percent of time exceeded is printed. This is based on the optimization criterion provided on the OC card.

(10) Cost Estimate Form for the Total Potential Capacity. The cost estimate for the total potential capacity is based either on CAPDES (PD.4) when it is supplied, or on the optimized installed capacity. Any cost extrapolation warning messages are printed above the cost estimate form.

(11) Summary of the Power Analysis. The summary of the power analysis tabulates the thirty items in Table 2 of the users manual for the potential, existing and incremental capacities. The potential capacity column is based on either the optimized total potential or CAPDES when it is provided (PD.4). When there is no existing capacity the potential and incremental capacity columns will be the same. When the potential capacity is greater than a non-zero existing capacity (C1.4), the incremental capacity column is based on the difference. If the optimized total potential, which is calculated internally, is less than the existing capacity, then the printed total potential column is set equal to the existing capacity column.

(12) <u>Plot of the Capacity-Duration Curve for Total Potential Capacity</u>. A plot of the capacity-duration curve is printed for the total potential. CAPDES on the plot is based on either the value supplied in field (PD.4) or is the optimized installed capacity. (Note that the asterisks on the plot override the alphanumeric characters).

EXHIBIT 5

USE OF HYDUR AS A SUBROUTINE

The HYDUR PROGRAM can be used as a subroutine to an existing program. For the purposes of this discussion, the users existing program will be referred to as EXIST. To accomplish this task the main program of the HYDUR PROGRAM called DRIVER is deleted and two labelled common blocks, type declarations, and a call statement are added to the program EXIST. The first common block called PØWIN as shown below supplies the hydropower routines with all the input variables that would normally be read on cards if HYDUR were run as a stand-alone program.

```
 COMMON/POWIN/AAEST, AMOR, AVGQ, CALCS, CAPDES, CB, CBFLAG, CBR, CEFS,
.CEMB, CIO, CLA, CMIS, CONT, COSTR, CPWH, CRATIO, CRC, SEBR, CSPW,
.SEAEND, REPL, CWWY, DCAP, DIST, DIV, EB, EBFLAG, ECAP, ECHOS, EFF,
.ERATIO, HEAD, HEIGHT, ICOMB, IPROJ, IREG, IVAR1, IVAR2, JSTATE, KS,
.NJOB, NOP, NPQ, NT, OP, OPER, OPERND, OVLOAD, PE, PLOTS, PSR, PTC,
.QDES, QFACT, QLOSS, QMIN, QQ, QSUB, RAAE, RATE, RESA, SRP, IPRTS,
.FLOWLO, T, TE, TH, TITLE, TQ, TRACE, TURB, TW, UAPF, WYL, WYQ, XUNITS,
.PEAKF, HMIN, HMAX, NINYR, INTBIAS, NCLUDE, NSEASN, NSEASKP, ISEASN,
.IPOWANL, LENREC, LSTRD, CAPYMN, NRDS, NPRO, CAPYMX, TERMCD, XTRP1,
.XTRP2

 INTEGER CALCS, CEFS, ECHOS, OPER, OPERND, PLOTS, TITLE(20,4), TRACE,
.TURB, XTRP1, XTRP2
 REAL CB(11), EB(11), OP(11), PE(70), QQ(70),
.TE(10), TH(10), TQ(10), TW(10)

 LOGICAL CBFLAG, EBFLAG, T(4), SEAEND
```

All of these variables are described in Exhibit 1.

The second common block PØWØUT contains all the important variables calculated in HYDUR. The definition of these variables is contained in Exhibit 1.

```
 COMMON/POWOUT/ AAE, AAEC, ACB, AEB, AEFF, AELC, AELQ, AFE, AHEAD,
.AHEADW, APF, AQ, AQGEN, ASE, ATAILW, BCR, CAPCTY, CBX, DC, DHEAD,
.EBX, IC, ICB, ICC, QDSIGN, TAB, TAC, TANB, EQF

 REAL IC, ICB, ICC
```

The call statement is as follows:

```
    CALL HYDUR (SWITCH)
```

When SWITCH, a logical variable, is 'TRUE' the variables contained within PØWIN must be defined in EXIST prior to the call statement. If SWITCH is 'FALSE' then the data cards normally read as input to the HYDUR program must be supplied. The location of the HYDUR data relative to the data read by EXIST will be dependent on where the call statement to HYDUR was inserted in program EXIST.

EXHIBIT 6

DATA ENTRY USING THE ALTERNATIVE FILE

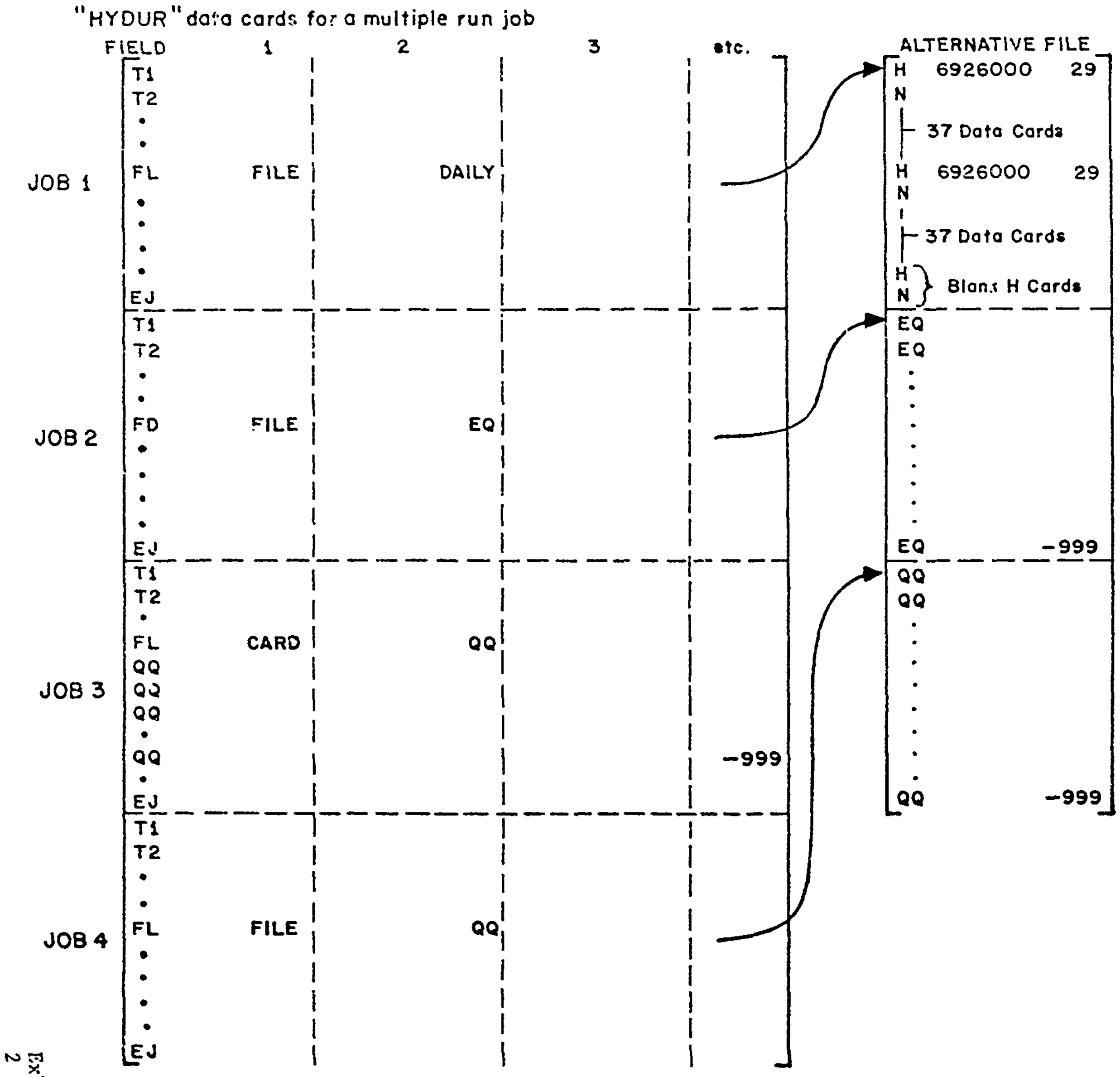
Sets of streamflow data or streamflow-duration coordinates can be read into the program from an alternative file. The first field on the FL and FD cards (see Exhibit 7) indicates hether the data sets are to be read by cards (using option CARD) or from the alternative file (using option FILE).

The alternative file is an external file that must be created prior to the execution of the HYDUR PROGRAM. The alternative file consists of all the data sets requested by the FILE option on the FL and FD cards. The data sets must be located on the alternative file in the same order as requested by the program. Each line of the alternative file consists of a card image which cannot exceed 150 characters in length.

The program reads data from the alternative file on Unit 3. If the user's alternative file is named XYZ, the user must associate this external (physical) file XYZ with the internal (logical) file named Unit 3. This task is accomplished through job control language (JCL) which varies from computer to computer. Examples 1, 2 and 3 describe how this is accomplished for three computer installations.

Figure 1 illustrates an example mutliple job run which requests three data sets from the alternative file. Job 1 on figure 1 reads daily streamflow data (FL.1 specifies DAILY) from the alternative file (FL.2 specifies FILE). After the program reads the FL card it commences to read data from the alternative file until a different streamgage number is encountered in the next set of header cards. In this example, this is accomplished by inserting a blank H and N card after the last daily streamflow card. The second job reads flow-duration data in STD format from the alternative file until the terminator code of -999 is encountered. Streamflow data are read from cards in the third job which demonstrates that jobs reading data sets from cards can be intermingled with jobs reading data sets from the alternative file. The fourth job reads streamflow data in STD format until the -999 is encountered.

After each data set is read from the alternative file, the file remains positioned to read the next data requested by the FL or FD card specifying the FILE option. End-of-record or end-of-file marks are <u>not</u> inserted between data sets.



Notes

Two years of streamflow data in "DAILY" format for station 6926000 in State 29. Each year of data requires 37 data cards. The last streamflow data card is followed by a blank H and N card.

Streamflow duration data on EQ cards in "STD" format. The end of the data is indicated by the terminator code -999. NOTE: JOB 3 read information from cards and not from the alternative file.

Streamflow data on QQ cards in "STD" format. The end of the data is indicated by the terminator code -999.

Figure 1. Use of the Alternative File to Read Flow Data

Example 1: JCL for CDC Computers at Boeing Computer Services

Methods A and B yield equivalent results. Methods assumed file (XYZ) is in users library.

Line	Method A	Method B
1	GET, TAPE 3 = XYZ.	GET, XYZ.
2	GET, HYDUR/UN = CECELB.	GET, HYDUR/UN = CECELB.
3	HYDUR.	HYDUR,,,,,,XYZ.
4	/*EOR (end-of-record card)	/*EOR (end-of-record card)
5	data cards	data cards
6	/*EOF (end-of-file card)	/*EOF (end-of-file card)

Method A

Line 1 creates a local copy of alternative file XYZ called TAPE 3. This matches the program's internal name for this file.

Method B

Line 1 creates a local copy of alternative file XYZ. In line 3, file substitution is used to create the association between internal file TAPE 3 and external file XYZ. (TAPE 3 is the sixth file named on the CDC "program" card in HYDUR).

Example 2: JCL for the CDC computers at Lawrence Berkeley Laboratory (LBL) in Berkeley, California.

Methods A and B yield equivalent results.

Line	Method A	Method B
1	FETCHPS,yourlib,TAPE3,XYZ.	FETCHPS,yourlib,XYZ,XYZ.
2	FETCHPS,HECLIB,HYDUR,HYDUR.	FETCHPS,HECLIB,HYDUR,HYDUR.
3	HYDUR.	HYDUR,,,,,,XYZ.
4	7/8/9 (end-of-record card)	7/8/9 (end-of-record card)
5	data cards	data cards
6	6/7/8/9 (end-of-file card)	6/7/8/9 (end-of-file card)

Method A

Line 1 creates a local copy of alternative file XYZ called TAPE 3 which is located on a user defined library (yourlib) in a subset, called XYZ. The name TAPE 3 matches the program's internal name for this file.

Method B

Line 1 creates a local copy of alternative file XYZ. In line 3, file substitution is used to create the association between internal file TAPE 3 and external file XYZ. (TAPE 3 is the sixth file named on the CDC "program" card in HYDUR.)

6/7/8/9 - multipunched

7/8/9 - multipunched

Example 3: JCL for IBM S360/370 computers

Only the basic JCL structure is shown. The user must supply other file-dependent and installation-dependent parameters.

```
//STEPA EXEC PGM=HYDUR

//FT01F001 DD DCB=(LRECL=     )

//FT02F001 DD DSN=         ,DCB=(RECFM=F,LRECL=80,     )

//FT06F001 DD SYSØUT=A

//FT05F001 DD *

  data cards

/*
```

Brief Description of FTO files:

FT01F001 Scratch file

If this is a formated write:

DCB=(RECFM=1,LRECL=m,   )

where m is the record size in bytes.

If this is an unformated write and the record size can vary (within or between runs) then:

DCB=(RECFM=V,LRECL=n,   )

where n=maximum bytes per record plus eight.

FT02F001 Alternative data file

FT06F001 Printed output

FT05F001 In-job card input

Exhibit 7

Input Description

September 1982

This exhibit contains a detailed description of each input card used by computer program "HYDUR". Many of the cards shown can be omitted if certain options are not required. The summary of input cards at the end of this exhibit shows the sequential arrangement of cards and the location of variables on the cards. The location of variables for each input card is shown by field number.

The standard format of input cards is ten fields of eight columns each except for Field 1. Variables in Field 1 occupy card columns 3-8 because card columns 1 and 2 (referred to as Field 0) are reserved for the required identification characters. Exceptions are cards adhering to a user-supplied format.

A free format field option is available that allows the user to separate input values by blanks or commas rather than using the standard (default = *FIXED) 10 fields of 8 columns each. This option is activated by inserting a separate card (preceding the T1 card) that has *FREE in columns 1-5. If subsequent jobs are provided in standard format, a *FIXED card MUST be inserted before the T1 card of the affected data set. The *FREE format option DOES NOT affect the QQ, H, N, daily GETUSGS streamflow, monthly GETUSGS streamflow, or EQ cards. These cards must all be in the exact format described in the subsection for each card.

Printing of the original input data (including flow values) is possible by use of the *NOPRINT and *PRINT cards, respectively. These two cards may be used throughout the job input data except that their use must not interrupt the sequence of streamflow data (QQ cards). Whenever one of these four commands (*FIXED, *FREE, *PRINT, *NOPRINT) is provided, it remains in effect until its logical counterpart is encountered. Jobs following a seasonal flow duration analysis will not be processed.

HYDUR INPUT DESCRIPTION

The different values a variable may assume and the conditions for each are described for each variable. Some variables are used simply to indicate whether or not a program option is to be used. The values for these variables are integers and must be right justified (punched on the far right side of the field) without any decimal points. Other variables are assigned numbers which express the variables' magnitude. For these, either a "+", or a "+ or -" is shown in the description under "value" and the numerical value of the variable is entered as input. A "+" indicates only a positive numerical value for this variable is appropriate. The "+ or -" allows for any non-zero value to be assigned. Where the variable's value is to be zero, the field may be left blank, since a blank field is read as zero and any number without a sign is considered positive. Unless noted otherwise, variable names beginning with the letters I, J, K, L, M, or N represent integer variables and a decimal point must not appear in the field. Certain variables (see the FL card, Field 1) in the Users Manual require that an exact alphanumeric code is to be entered to indicate a program option. The values should be right justified in the indicated field of the card without quotations. The location of variables on cards is sometimes referred to by an abbreviated designation, for example, FM.4 means the fourth field of the FM card.

All cards are optional unless they are specifically identified as being required. The default values for each variable, if assigned by the program, are shown in parentheses under the variable name.

Several jobs may be processed at the same time by stacking the respective data decks. The program automatically saves the values from each input card. Subsequent jobs only require new cards or cards whose values have changed from the previous job. Whenever an input card replaces a card from the previous job, all input fields on the new card must be specified. Caution: If a subsequent job does not need a particular card that was used in a previous job, then a card with the proper 2-column identifier should be included with all fields left blank.

HYDUR INPUT DESCRIPTION

Summary of Program Usage Options*

OPTION	DESCRIPTION	NECESSARY CARDS
1A	Calculation of a flow duration curve from streamflow data	T1, T2, T3, T4, FL, EJ, plus one of the following: (1) QQ cards including sets of H, N the 37 daily flow cards for each year (2) or record; H and N cards and monthly flows; (3) or flows in user specified format (FM card required).
1B	Calculation of seasonal duration curves(s) from streamflow data	T1, T2, T3, T4, SD, FL, EJ plus one of the following: (1) QQ cards including sets of H, N and 37 daily flow cards for each year of record; (2) H and N cards and monthly flows; (3) or flows in user specified format (FM card required).
2A	Calculation of average annual energy from streamflow data	Cards from Option 1 and at users's discretion the PD, PQ, TQ, TE, TW, TH card(s).
2B	Calculation of seasonal energy production from streamflow data	Same as Option 1B with the addition of S1, S2, SO and/of SS cards.
3	Calculation of average annual energy from flow duration data	T1, T2, T3, T4, FD, EJ, plus one of the following: (1) EQ cards; (2) streamflow duration coordinates in GETUSGS format; or (3) streamflow duration coordinates in user supplied format (FM card required). As options the PD, PQ, TQ, TE, TH card(s).

*Required cards for all options: T1, T2, T3, T4, EJ either FL or FD must be provided. PD is usually a required card.

Summary of Program Usage Options*

OPTION	DESCRIPTION	NECESSARY CARDS
4	Optimization of capacity	Option 2 or Option 3 cards plus the OC card. If costs and benefits are analyzed these data must be entered as explained in Option 5 and 6.
5	Calculation of project benefits	Either the PB card, or the CB and EB cards. Or MC and ME cards.
6	Calculation of project costs	C1 and/or C2 cards. CF card is optional.

*Required cards for all options: T1, T2, T3, T4, EJ either FL or FD must be provided. PD is usually a required card.

HYDUR INPUT DESCRIPTION

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

1 GENERAL PURPOSE CARDS

1.1 T1,T2,T3 AND T4 - Title Cards (Required)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	T1,T2 T3 or T4	Card identification characters.
1-10	TITLE	ALPHA	Alphanumeric information to identify the job. Information on the T4 card is not retained for future jobs.

1.2 AF CARD - Adjustment Factors (Optional)

The AF card specifies units of measurement used in HYDUR.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	AF	Card identification characters.
1	SYSTEM (ENGLSH)	METRIC	All input values are in metric units. Flows in cubic meters/second and lengths in meters.
		ENGLSH	All input values are in english units. Flows in cubic feet/second (cfs) and lengths in feet.
2	ALEN (1.0)	+	Adjustment factor multiplied times the display of all length (feet or meters) related parameters.
3	APWR (1.0)	+	Adjustment factor multiplied times the display of all power (kw) related parameters.
4	AENRG (1.0)	+	Adjustment factor multiplied times the display of all energy (mwh) related parameters.
5	ADOLR (1.0)	+	Adjustment factor multiplied times the display of all money ($) parameters.
6	AFLOW (1.0)	+	Adjustment factor multiplied times the display of all flow (cfs or cms) related parameters.

1.3 C CARDS - Comment Cards (Optional)

Comment cards enable the user to insert documentation information throughout the input card stream. Comment cards are displayed in the echo printing of the input job (T1-EJ) but have no effect on the operation of the program. Any number of comment cards can be inserted. The only restriction is that they cannot be inserted between flow values (FL through QQ cards).

2 STREAMFLOW DATA CARDS (Optional)

Streamflow cards SD, S1, S2, SO, SS, FL, FM, QQ, are used to develop a duration curve from streamflow values. The streamflow cards in this section are omitted if the streamflow duration curve is input directly or if a flow duration curves is used from a previous job in stacked jobs. These cards are required only when flow duration cards are omitted.

2.1 SD CARD - Seasonal Duration Parameters (Optional)

The user is cautioned that the seasonal duration option of HYDUR has not undergone extensive testing. If probelms occur, it is recommended that the normal annual analyses be performed.

The SD card is used to develop streamflow duration curves for specified time intervals. The time interval (season) may vary from one month to one year in duration. This card is used only in conjunction with streamflow values input on FL cards. The SD card must precede the FL card in the input sequence of a job. If no SD card is supplied or if the above requirement is not met, an annual streamflow duration curve is developed.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	SD	Card identification characters.
1	INTBIAS (0)	+	The number of streamflow values to skip before beginning the first streamflow-duration analysis. Maximum value is defined in Field 3 (NINYR).
2	NCLUDE (value in SD.3)	+	Defines the number of consecutive streamflow values to include in the development of duration curve(s) once the proper starting position has been determined. Additional flows from subsequent years of record, which are to be incorporated in the duration curve, are found by skipping ((SD.3) - (SD.2)) values.

FIELD	VARIABLE	VALUE	DESCRIPTION
3	NINYR (0)	+	A value is required if seasonal analysis is to be performed. Defines the number of streamflow values which comprise a year. For monthly streamflow records, this value would be twelve (12). For daily flow records, this value should be 365 for blocked records required (12*31) or 372 daily flows to be read per year. This type of input requires negative flow values to be read for non-existent days, such as February 31. If FL.2 = DAILY and NINYR=372, then GETUSGS daily blocked data will be expected.
4	NSEASN (1)	+	Defines the number of seasons to be analyzed. A different streamflow duration curve is developed for each season.
5	NSEASKP (value in SD.2)	+	The number of streamflow values to skip for each season. This value is added to an accumulator each time a new season is processed and the accumulated value determines the starting position for each season. The user can set this parameter to allow for overlapping of streamflows from one season to the next. The maximum value for this parameter is determined by the ratio ((SD.3)/(SD.4)).
6*	CAPYMX (0)	- or 0	For annual power analyses (SD.2 = SD.3), no restriction to an upper limit is considered. For seasonal power analyses (SD.2 less than SD.3), the program selects this upper limit based on scanning the flow record (QQ cards).

*The use of this option results in the OP card being ignored. Instead, intermediate capacities are determined based upon a constant interval determined by the following equation:

BINTV = (CAPYMX-CAPYMN)/(N-1)

where:

N represents the total number of capacity values to consider.

FIELD	VARIABLE	VALUE	DESCRIPTION
		+	The maximum installed capacity (in kilowatts) considered in subsequent optimization analyses.
7*	CAPYMN (0)	- or 0	For annual power analyses (SD.2 = SD.3), no restriction to a lower limit of installed capacity in subsequent optimization analyses is considered. For seasonal power analyses (SD.2 less than SD.3), the program selects this lower limit based on scanning the flow record (QQ cards).
		+	The minimum installed capacity (in kilowatts) considered in subsequent optimizations analyses.

*The use of this option results in the OP card being ignored. Instead, intermediate capacities are determined based upon a constant interval determined by the following equation:

BINTV = (CAPYMX-CAPYMN)/(N-1)

where:

N represents the total number of capacity values to consider.

The following set of optional cards (S1, S2, SO and SS) enable the user to vary parameters which typically change with time (season). An SD card must be input in this job.

2.2 S1 CARDS - Seasonal Upstream Diversions (Optional)

The S1 card specifies upstream diversions to be varied by season. The use of this card results in variable DIV (PQ.3) to be overridden for each season analyzed. A maximum of 12 values may be input (two S1 cards); however, only the first SD.4 values will be used in the concurrent job.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	S1	Card identification characters.
1-10	SDIV	+ or -	Upstream diversions (in cfs or cms) varying by season. Up to 12 values, input in groups of 10 values per card, are allowed. Once the maximum number has been defined, additional S1 card input is ignored.

2.3 S2 CARDS - Seasonal Losses at Dam Sitė (Optional)

The S2 card specifies seasonable tailwater losses. The S2 card overrides variable QLOSS (PQ.4). Input limitations and requirements are identical to those defined for the S1 card.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	S2	Card identification characters.
1-10	SQL	+ or -	Seasonal losses effecting tailwater (in cfs or cms).

2.4 SO CARDS - Seasonal Operation of Plant (Optional)

The SO card specifies seasonal plant operation (seasonal plant factor). The SO card overrides variable VAPF (PD.6). Input limitations and requirements are identical to those defined for S1 card.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	SO	Card identification characters.
1-10	SPF	+	Plant factor (greater than zero and less than one) values.

2.5 SS CARDS - Seasonal Power Storages (Optional)

The SS card specifies seasonal reservoir storage (power storage ratios). The SS card overrides variable PSR (PD.7). Input limitations and requirements are identical to those defined for the S1 card.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	SS	Card identification characters.
1-10	SSR		Seasonal power storage ratios (greater than or equal to zero).

2.6 FL CARD - Flow Card (Required unless FD is provided)

The FL card is required if streamflow data are used to calculate the streamflow duration curve. This card is omitted when a streamflow duration curve is input on FD cards or when a flow duration curve from a previous job is used.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	FL	Card identification characters.
1	FTYPE (card)	CARD	Streamflow data will be read by cards (input file).
		FILE	Streamflow data will be read from a separate alternative file on Unit 3. (See Exhibit 6 in Users Manual.).
2	FMTYPE (STD)	STD	Streamflow values are provided on QQ cards in standard card format of 10F8.0.
		DAILY	Average daily streamflow data will be provided in GETUSGS sequential or blocked format including header cards.
		MONTH	Average monthly streamflow data will be provided in GETUSGS format including header cards.
		USER	Streamflow data is provided in user supplied format. When this option is selected, the FM card must be the next input card provided.
3	PUNCH (NOPUNCH)	NOPUNCH	Streamflow duration ordinates will not be punched on cards during this job.
		PUNCH	Pairs of percent of time and streamflow ordinates on the streamflow duration curve will be punched in standard (FL.2 equals STD) format of 10F8.0 during this job.
4	POWANAL (YES)	YES	Power analysis will be performed (after generating the streamflow duration curve). PD card is required.

FIELD	VARIABLE	VALUE	DESCRIPTION
		NO	Power analysis will not be performed. Only streamflow-duration curve will be generated.
5	LENREC (80)		This parameter is required if variable FTYPE (FL.1) equals FILE. FILE defines the record length of the alternative file.
		0	Record length is assumed to be equal to a typical card image of eighty (80) columns.
		+	Record length of alternate file (not to exceed 150). For example, if streamflows on the alternative file are written using the format of (7X,5F8.2), then the corresponding record length would be ((7+(5*8)) or 47.
6	FLOWLO (0)	+,-,0	Discharge values less than this value (FLOWLO) will not be considered in determining the flow-duration curve.

FM

2.7 FM CARD - User Specified Format Card (Optional)

The FM card is required when variable FMTYPE (FL.2 or FD.2) is equal to USER, the FM card indicates format of the user supplied data and the number of streamflow or streamflow duration data values. Either variable TERM (FM.1) which specifies a user supplied terminator code, or variable ITVALS (FM.2) which specifies the number of streamflow data values or pairs of streamflow duration ordinates, must be provided.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	FM	Card identification characters.
1	TERM (-999)	0	Variable ITVALS (FM.2) will be used to indicate the number of streamflow values or pairs of streamflow duration data values or the default value (-999) will be used if ITVALS is blank.
		+ or -	Streamflow or streamflow duration ordinates are to be read until TERM is encountered. The absolute value of TERM should be greater than or equal to 1.0, and placed in the field immediately following the last data value.
2	ITVALS (0)	0	Variable TERM (FM.1) indicates the end of the streamflow or flow duration data.
		+	Number of user specified streamflows (or pairs of flows and percent of time exceeded ordinates) to be read.
3	NVALS	+	Number of streamflow (or pair) values specified in the user designed format on fields 4-10 of the FM card.
4-10	FMT	ALPHA	User supplied format for streamflow data or the flow duration curve. Flow duration ordinates must be specified in pairs of percent of time exceeded and flow values. Parentheses must be included, e.g., (8X,6F6.0). The specification may be continued to the following card by specifying another FM card and continuing the format in column 3.

2.8 QQ CARDS - Streamflow Data Cards

The QQ cards specify streamflow values when variable FMTYPE (FL.2) is equal to "STD". The QQ is not required in the first two columns. The last streamflow value must be -999. The QQ cards follow the FL card.

FIELD	VARIABLE	VALUE	DESCRIPTION
1-10	FLOWS	+	Streamflow values in cfs or cms.
		-	Missing data values should be indicated by entering a negative number (see Field FL.6).
		-999	Required terminator code that must immediately follow the last streamflow value.

3 FLOW DURATION DATA (Required unless streamflow data cards are used)

The FD, FM, and EQ cards specify criteria for inputting streamflow duration curves. When individual streamflow values are provided the cards in this section are omitted.

3.1 FD CARD - Flow Duration Card (Required unless FL is provided)

The FD card is required if streamflow duration data are to be input. This card is omitted when streamflow data are specify on the FL card or a flow-duration curve from a previous job is used.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	FD	Card identification characters.
1	FTYPE (CARD)	CARD	The flow duration curve will be input by cards.
		FILE	The flow duration curve will be input from a separate alternative file on Unit 3. (See Exhibit 6 in Users Manual).
2	FMTYPE	STD	Streamflow duration and corresponding percent of time exceeded values are provided in standard card format - 10F8.0 (see EQ cards). Data must be terminated by -999.
		USER	Streamflow duration and percent of time exceeded values are provided in user supplied format. The FM card must immediately follow the FD card.

TABLE 2: Standard Two Letter Postal and Two Digit FIPS Codes

AL --- 01 --- ALABAMA
AK --- 02 --- ALASKA
AZ --- 04 --- ARIZONA
AR --- 05 --- ARKANSAS
CA --- 06 --- CALIFORNIA
CO --- 08 --- COLORADO
CT --- 09 --- CONNECTICUT
DE --- 10 --- DELAWARE
DC --- 11 --- DISTRICT OF COLUMBIA
FL --- 12 --- FLORIDA
GA --- 13 --- GEORGIA
HI --- 15 --- HAWAII
ID --- 16 --- IDAHO
IL --- 17 --- ILLINOIS
IN --- 18 --- INDIANA
IA --- 19 --- IOWA
KS --- 20 --- KANSAS
KY --- 21 --- KENTUCKY
LA --- 22 --- LOUISIANA
ME --- 23 --- MAINE
MD --- 24 --- MARYLAND
MA --- 25 --- MASSACHUSETTS
MI --- 26 --- MICHIGAN
MN --- 27 --- MINNESOTA
MS --- 28 --- MISSISSIPPI
MO --- 29 --- MISSOURI
MT --- 30 --- MONTANA
NE --- 31 --- NEBRASKA
NV --- 32 --- NEVADA
NH --- 33 --- NEW HAMPSHIRE
NJ --- 34 --- NEW JERSEY
NM --- 35 --- NEW MEXICO
NY --- 36 --- NEW YORK
NC --- 37 --- NORTH CAROLINA
ND --- 38 --- NORTH DAKOTA
OH --- 39 --- OHIO
OK --- 40 --- OKLAHOMA
OR --- 41 --- OREGON
PA --- 42 --- PENNSYLVANIA
RI --- 44 --- RHODE ISLAND
SC --- 45 --- SOUTH CAROLINA
SD --- 46 --- SOUTH DAKOTA
TN --- 47 --- TENNESSEE
TX --- 48 --- TEXAS
UT --- 49 --- UTAH
VT --- 50 --- VERMONT
VA --- 51 --- VIRGINIA
WA --- 53 --- WASHINGTON
WV --- 54 --- WEST VIRGINIA
WI --- 55 --- WISCONSIN
WY --- 56 --- WYOMING

3.2 FM CARD - User Specified Format Card

The FM card is required to specify the format of the duration data when FD.2 equals "USERS" (see Section 2.7).

3.3 EQ CARD - Exceedance Flow Data Card

The EQ card is required to specify ordinates on the streamflow duration curve when FD.2 is equal to "STD". The "EQ" is not required in the first two columns. The last pair of streamflow duration coordinates must be followed by a -999. A maximum of 70 pairs of PE and QQ values may be input.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	EQ	Card identification characters (optional).
1	PE(1)	+	First ordinate for percent of time exceeded oridnate expressed as percent or as a decimal fraction. Values input in decreasing order.
		-999	Required terminator code that immediately follows the last streamflow value.
2	QQ(1)	+	First ordinate streamflow in cfs or cubic meters/second corresponding with variable PE (EQ.1), values are input in increasing order.
3-10	PE(N),QQ(N)	+	Same as above for up to 70 pairs of ordinates.

3.4 GETUSGS STREAMFLOW DURATION CURVE

These cards are required when FD.2 is equal to "FLDUR". The GETUSGS consists of a header card followed by pairs of flow duration ordinates. The number of pairs of streamflow duration coordinates must be indicated by either "NPQ" on the header card or the last percent of time ordinate must be followed by a -999. Must follow the FD card.

NOTE: GETUSGS data is stored in english units only (cfs). Therefore, using the metric option requires an adjustment factor to be specified in field (PQ.5).

HEADER CARD

FORMAT	COLUMN	VARIABLE	VALUE	DESCRIPTION
I2	1-2	ISTATE	+	Two digit state FIPS code from Table 2 (Exhibit 7).
I8	3-10	IGAUGE	+	Eight digit integer USERS gage number.
I2	11-12	NPQ	+	Number of pairs of discharge and Percent of time exceeded ordinates used to describe the streamflow duration curve.

DATA CARDS

Supply data cards as needed - 5 pairs of (QQ, PE) per card.

FORMAT	COLUMN	VARIABLE	VALUE	DESCRIPTION
F10.2	1-10	QQ	+	First discharge in cfs (lowest discharge).
F6.1	11-16	PE	+	First percent of time exceeded ordinate corresponding to the discharge.
4(F10.2,F6.1)	17-80	QQ,PE	+	Subsequent pairs of QQ and PE values are provided.

4 POWER DATA

The PD, PQ, TQ, TE, TH, and TW cards define the power generating characteristics of the power plant, the assumed head, and flow characteristics.

4.1 PD CARD - Power Design Parameters Card (usually a required card)

The PD card specifies design parameters for the power facility. The value CAPDES specifies if an optimization analysis is to be performed.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	PD	Card identification characters.
1	QDES	0	The maximum penstock discharge capacity will be calculated based on the installed capacity, overload factor of the plant, efficiency, and head (see Equation 2). For optimization analyses, variable CAPDES (PD.4) equals zero, QDES is set equal to the selcted discharge from the flow duration curve.
		+	Maximum penstock discharge capacity in cfs or cms.
2	EFF (0.86)	0	Powerplant efficiency (TE card) corresponding to the maximum penstock discharge capacity will be used. If TE card is not input the efficiency of .86 is used.
		+	The design powerplant efficiency expressed as a decimal fraction. Powerplant efficiency equals the efficiency of the turbine times the efficiency of the generator.
3	HEAD	0	The head will be determined from the head elevation (TH card) and tailwater elevation (TW card) data.

FIELD	VARIABLE	VALUE	DESCRIPTION
		+	The net design head of the turbine in feet or meters. Constant head for all power calculations, head elevation tailwater data (TH) and TW are not input.
4	CAPDES (0)	0	Plant capacity will be optimized based on criteria specified on the OC card.
		+	Installed powerplant nameplate capacity in kilowatts.
5	OVLOAD (1.15)	+	Overload factor for the power installation. Input as a decimal to be multplied by variable CAPDES (PD.4).
6	UAPF (1.0)		User defined annual plant factor which represents the annual plant factor required to meet annual firm energy requirements. UAPF can be expressed as: UAPF = AFE/(DC*8.76) · ere: AFE = annual firm energy in mwh DC = dependable capacity in kw A value other than 1.0 will affect net power head calculations since the factor will be used to adjust discharge values to approximate the flows at the time of actual hydropower operation.
		0	Annual plant factor value is not used to adjust flows in the calculation of the tailwater elevation.
		+	Annual plant factor (value between 0 and 1), divided into the discharge values to account for increased tailwater elevations encountered in peaking operations.
7	PSR	0	No adjustment to flow-duration curve. Flow duration curve assumed to represent flow pattern available for power generation.

PD

FIELD	VARIABLE	VALUE	DESCRIPTION
		+	Power storage ratio (PSR) used to adjust the flow-duration curve to account for project storage (see Exhibit 2). Equals the power storage in acre-feet divided by the product of 722.50 and average annual inflow in cfs.
		-	Power storage ratio (PSR) used to adjust the flow-duration curve to account for project storage as a function of the average annual draft rate (see Exhibit 2).
8	XUNITS	0	The number of units required to deliver the plant's installed capacity will be determined by selecting a unit design discharge equal to the flow corresponding to an exceedence percent of 75. EXAMPLE: The design discharge of a plant is 5000 cfs and that the 75 percent exceedence flow value is 3000 cfs, the number of units assigned by the program would be: (5000/3000)+1 = 2.67 or 2 units
		+	Number of units (up to 50) assumed in place for this job. Combined capacities equal the total installed plant capacity. NOTE: If the project is presently in place, and ECAP (C1.4) is greater than zero, existing and total units assumed installed are defined as: existing units to the right of the decimal and total units to the left. For example, the input value to define a total of four (4) units, three (3) of which are presently in place, would be 4.03.
9	PEAKF (1.0)	0	Peaking adjustm' : factor. No adjustment to capacities determined in the optimization analysis will be made.
		+	The peaking adjustment factor (between 1 and 10) will be used to adjust (multiplied by) design discharge values obtained in the optimization analysis. NOTE: If the maximum installed capacity, variable CAPYMX (SD.6), is greater than zero no adjustment is made.

4.2 PQ CARD - Power Flow Card

The PQ card specifies flow constraints on the water available to produce power.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	PQ	Card identification characters.
1	QSUB (0)	0	Submergence flow is not considered.
		+	Submergence flow in cfs or cms. No power generated for discharge values greater than input value.
2	QMIN (0)	+	Minimum flow in cfs or cms. No power is generated for discharges less than QMIN. Absolute input values less than one will cause QMIN to be defined as a percentage of the design discharge, using the following equation: QMIN = PER*QD/XUNITS where: PER = input value where absolute value is less than one QD = current design q value. (this value will vary during optimization runs XUNITS = Number of power units installed (PD.8) NOTE: QMIN is adjusted to reflect peaking operation if variable VAPF (PD.6) is less than 1.0.
.	DIV (0)	+	Flow diversion in cfs or cms above the powerhouse (average evaporation losses may be included in DIV). Value is subtracted from the streamflow values on the flow duration curve before performing the power analysis.

PQ

FIELD	VARIABLE	VALUE	DESCRIPTION
4	QLOSST (0)	+	Diversion of water in cfs or cms around the powerhouse (fish ladder, leakage, etc.). This flow is not used for power production but affects the headwater and tailwater elevations.
5	QFACT (0)	0	No adjustment will be made to streamflow values on flow duration curve prior to power analysis.
		+	Adjustment (multiplier) factor to streamflow values on flow duration curve prior to performing the power analysis (e.g., drainage area adjustment, etc.).
6	HMIN (0)	+	Minimum head required to produce power. No power is generated for powerheads less than input value (a value less than 1.0 implies the minimum head will be calculated as the product of HMIN times the design head).
7	HMAX (0)	+	Maximum head allowed to produce power. No power is generated for powerheads greater than HMAX (a value less than 2.0 implies the maximum head will be calculated as the product of HMAX times the design head).
8	SPLEF (YES)	BLANK OR YES	Spillage from the reservoir will affect the tailwater conditions at the powerhouse. Typically occurs at overfall dams where the draft tubes exit below the base of the dam.
		NO	Spillage from the reservoir will not affect the tailwater conditions at the powerhouse. This condition exists at installations where the powerhouse and spillway are separated from one another.

4.3 TQ CARD - Discharges Values Card

The TQ card specifies discharge values associated with the operation efficiencies, headwater and tailwater elevations (TE, TH, and TW cards, respectively). A maximum of 10 entries is allowed. TQ-TW cards may be omitted if the constant head, HEAD (PD.3) and efficiency, variable EFF (PD.2) are input.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	TQ	Card identification characters.
1	TQ(1)	+	Reservoir discharge in cfs or cms. Corresponds to operating efficiency (TE(1)), headwater elevation (TH(1)), and tailwater elevations (TW(1)).
2-10	TQ(N)	+	Same as above for up to 10 values.

4.4 TE CARD - Table of Efficiencies Card

The TE card specifies the combined operating efficiencies of the turbine and generator units. These values correspond to the discharge values on the same field of the TQ card. A TQ card must be input for each TE card.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	TE	Card identification characters.
1	TE(1)	+	Operating efficiencies expressed as decimal fractions corresponding to discharge values on the first field of the TQ card.
2-10	TE(N)	+	Same as above for up to 10 values.

TH
TW

4.5 TH CARD - Table of Headwater Elevations Card

The TH card specifies the elevation of the headwater. Elevations are in increasing order. If this card is omitted then the design head on the variable HEAD (PD.3) will be used in the power equation.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	TH	Card identification characters.
1	TH(1)	+	Headwater elevation in feet or meters corresponding to the discharge values on the first field of the TQ card
2-10	TH(N)	+	Same as above for up to 10 values.

4.6 TW CARD - Table of Tailwater Elevations Card

The TW card specifies the elevation of the tailwater.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	TW	Card identification characters.
1	TW(1)	+	Tailwater elevation in feet or meters corresponding to the discharge vaue on the first field of the TQ card.
2-10	TW(N)	+	Same as above for up to 10 values.

5 POWER BENEFIT INFORMATION

Benefit information cards (PB, CB, EB, MC, ME, and EF cards) are required when benefit computations are to be performed. If the optimization analysis (OC card) specifieds benefits, net cost, or B/C ratios, etc. are to be optimized then either variable IREG (PB.1), or (CB and EB), or (MC and ME) card are required.

5.1 PB CARD - Power Benefit Card

The PB card is required when power benefits from one of the 32 FERC regions (see Table 1B) are desired.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	PB	Card identification characters.
1	IREG (0)	0	Power and energy benefits are specified on CB and EB cards or MC and ME cards.
		+	Two digit integer region code from Table 1A/B (page 14) main test. FERC energy and capacity benefits from the region illustrated on Figure 4 in the Users Manual are applied in the program. NOTE: Benefit relationship developed are functionally related to plant factor, since this parameter is often a good indicator of the least-cost alternative to hydropower facilities. Storage projects often use this approach in determining benefits. However, it may not be appropriate for run-of-river projects. Values for energy (capacity if appropriate) should be determined by fuel displacement (or similar) analysis and input using the EB card.
2	CBR (0.50)		Capacity benefit reduction factor that is multiplied times the capacity benefit to determine the interruptible capacity benefit.

PB

FIELD	VARIABLE	VALUE	DESCRIPTION
		0	A capacity reudction factor of .50 will be multiplied times the capacity benefit to determine the interruptible capacity benefit.
		+	Capacity benefit reduction factor (between 0 and 1.0) to be multiplied times the capacity to determine the interruptible benefit.
3	DCAP (value in PB.6)	0	The dependable capacity is based on the value input on variable SRP(PB.6).
		+	Dependable capacity in kilowatts used to calculate the capacity benefit.
4	AAEST	0	Average annual energy will be calculated by the program to determine the energy benefit.
		+	Average annual energy in kilowatt-hours to be used in calculation of the energy benefit (in place of calculated energy).
5	RAAE	0	No ratio is used. No adjustment will be made to the calculated energy used to determine benefits.
		+	Ratio (decimal vaue) multiplied times the average annual energy to adjust the energy used in the benefit computations.
6	SRP (0.85)	0	Default value of 0.85 will be used to select the discharge value on the duration curve used to calculate dependable energy. Must be zero if variable DCAP (PB.3) is positive.
		+	Streamflow reliability percentage (decimal value on the) used to select discharge value flow duration curve for use in calculation of dependable capacity.
7	ERATIO	0	No adjustment will be made to the energy benefit determined from Table 1A (page 12) of text.
		+	Adjustment factor (decimal) to be multiplied times the FERC energy values (1978 dollars) from Table 1A of text.

PB

FIELD	VARIABLE	VALUE	DESCRIPTION
8	CRATIO	0	No adjustment will be made to the capacity benefit obtained from Table 1B (page 13) of text.
		+	Adjustment factor (decimal) to be multiplied times the FERC capacity value (1978 dollars) from Table 1B (page 14) of text.
9	SEBR	0	Default value of 0.50 will be used for the adjustment factor to be multiplied times the firm energy benefit to determine the secondary energy benefit rate (see EF card).
		+	Adjustment factor (between 0 and 1.0) to be multiplied times time firm energy benefit to determine the secondary energy benefit rate (see EF card).

CB

5.2 CB CARDS - Capacity Benefit Cards

The CB cards are provided when capacity benefit cards are required when variable IREG (PB.1) is zero (or PB card is omitted), and benefit calculations are desired. The capacity benefit is provided as a function of the annual plant factor (APF). The 11 fields (2 cards required) indicate the benefit corresponding to values of APF from 0 to 1.0 in increments of 0.10. For a constant vaue of capacity benefits (regardless of plant factor), input the same capacity benefit eleven times.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	CB	Card identification characters.
1-11	CB	+	Capacity benefit corresponding to appropraite APF in units of $/kw-yr. Field 11 is input in first field of second CB card.
12	CRATIO	0	No adjustment will be made to capacity benefits provided on the first 11 fields of the CB cards.
		+	Adjustment factor (decimal) to be multiplied times the capacity benefits on Fields 1-11 of the CB card. Field 12 is input in the second field of second CB card.

5.3 EB CARDS - Energy Benefits Cards

Energy benefit cards are required when variable IREG (PB.1) is zero (or PB card is omitted), and benefit calculations are desired. The cards indicate the energy benefit is a function of APF. for a constant value of energy benefit (regardless of plant factor), input the same energy benefit eleven times.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	EB	Card identification characters.
1-11	EB	+	Energy benefit corresponding to appropriate APF in units of $/mwh. Field 11 is input on the first of the second EB cards.
12	ERATIO	0	No adjustment will be made to the energy benefits provied on the first eleven fields of the EB cards.
		+	Adjustment factor (decimal) to be multiplied times the energy benefits specified on the first eleven fields of the EB card. Field 12 is input on the second field of the EB card.

MC
ME

5.4 MC CARD(S) - Seasonal Capacity Benefits

The MC card specifies seasonal capacity benefits. The use of the MC card overrides values input for variable IREG (PB.1) or the CB card.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	MC	Card identification characters.
1-11	CMAF	+ or 0	Capacity benefit for each season required. The eleventh value is input in the first field of the second MC card.

5.5 ME CARD(S) - Seasonal Energy Benefits

The ME card specifies seasonal enegy benefits. The use of ME card overrides input values for variable IREG (PB.1) or for the EB card.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ME	Card identification characters.
1-11	EMAF	+ or 0	Energy benefit for each season. The eleventh value is input in the first field of the second ME card.

5.6 EF CARDS - Equivalent Firm Energy Benefits

The EF card specifies the value of secondary energy in terms of an equivalent firm energy value. The equivalent firm energy value may range between 0.0 and 1.0 and is related to the percent of time the secondary energy is available. As the availability of secondary energy approaches 100 percent, its value becomes equal to the firm energy value.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	EF	Card identification characters
1-11	SEFV	+ or 0	Equivalent firm energy values corresponding to the availability of the secondary energy in terms of an annual percentage. Input eleven (11) values corresponding to the following availability percentages: (0,10,20,30,40,50,60,70,80,90,100). The eleventh value is input in the first field of the second EF card.

C1

6 POWER COST INFORMATION

Power cost cards (C1, C2 and CF cards) specify cost information for analysis desired.

6.1 C1 CARD - First Card - Cost of Construction

The C1 card specifies information on the size of the project and related components.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	C1	Card identification characters.
1	HEIGHT (0)	0	No embankment costs are calculated.
		+	Height of the dam in feet or meters. This value is used in the computation of embankment costs.
2	DIST (0)	0	No embankment costs are calculated.
		+	Length of the dam crest in feet or meters. This value is used in the computation of embankment costs.
3	KS (0)		Valley shape coefficient. This value is used to determine estimated embankment costs. Various shapes are shown Figure 1 (page 38).
		0	No embankment costs are calculated.
		1	Trapezoidal (Type A)
		2	Triangular (Type B)
		3	Trapezoidal river section with a trianglar overbank (Type C).

FIELD	VARIABLE	VALUE	DESCRIPTION
4	ECAP (0)	0	Existing capacity is not in place.
		+	Existing capacity at proposed site. The specified or calculated value of CAPDES (PD.4) (installed capacity) is assumed to be the capacity added to ECAP.
5	OPER (L)	L	Powerhouse is locally operated. Used in estimating OM&R costs. User should assume local operation unless it is known that project is remotely operated.
		R	Powerhouse is operated from a remote site. Used in OM&R cost estimates.
6	TURB (0)		Three character code for setting extrapolation flags in determining powerhouse cost and for indicating the type of turbine to be installed. If zero, extrapolation of powerhouse costs will not occur. The program will select the types of units.
			The first or second characters may be:
		C	Extrapolation of capacity arrays is allowed in determining powerhouse costs.
		H	Extrapolation of head arrays is allowed in determining powerhouse costs.
			NOTE: If neither code is specified, extrapolation is not allowed and a total annual cost of 9999999999 is assumed for the installation.
			The third character (or first if C and H not used) may be:
		0	Program selects the type of turbine.
		F	Francis unit.
		K	Kaplan unit (usually above 10 megawatts).
		S	Small kaplan unit (less than 10 megawatts).
		T	Tube turbine

C1

FIELD	VARIABLE	VALUE	DESCRIPTION
7	RESA (0)	0	Reservoir acquisition and clearing costs are not calculated.
		+	Reservoir area in acres or square kilometers. Used to determine land acquisition, clearing and preparation costs.
8	WYL (0)	0	No waterway costs are calcualted.
		+	Length in feet or meters of waterway or diversion canal that transports water to the powerhouse.
9	WYQ (0)	0	No waterway costs are calculated.
		+	Maximum discharge in cfs or cms associated with the waterway specified in C1.8.
10	IPROJ (0)		Code indicating components included in the cost calcuations. The sum of the following codes deletes the specified project components from the cost calculations. When IPROJ is specified, it will override a request for cost computations on Fields 1-9.
		0	All components, including a waterway, are included in the cost calculations.
		1	Delete waterway costs. (Fields C1.8 and C1.9 do not need to be specified.)
		2	Delete embankment costs. (Fields C1.1, C1.2 and C1.3 do not need to be specified.)
		4	Delete spillway costs.
		8	Delete reservoir clearing costs.
		16	Delete land acquisition costs.
		32	Delete cost of the inlet and outlets.
		64	Delete costs of the powerplant
		128	Delete operation, maintenance, and replacement costs.

FIGURE 1: VALLEY SHAPE CODES

```
     1------- 1 --------1
   - xxxxxxxxxxxxxxxxxxxx
   1  x                x
   h   x              x
   1    x            x
   -     xxxxxxxxxxxx
```

TYPE A. TRAPEZOIDAL RIVER CROSS SECTION

```
   -     xxxxxxxxxxx
   1      x       x
   1       x     x
   h        x   x
   1         x x
   -          x
```

TYPE B. TRIANGULAR RIVER CROSS SECTION

```
   -     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
   1        x                      x
               x                x
   h    -         x           x
        1          x         x
   1   h/2          x      x
   -    -            xxxxxx
                     -1/6--
```

TYPE C. TRAPEZOIDAL RIVER CROSS SECTION WITH TRIANGULAR OVERBANK

C2

6.2 C2 CARD - Second Card - Cost of Construction

The C2 card enables users to specify actual rather than general (C1 card) cost information. Whenever actual costs are provided they will override costs that are automatically calculated. When ECAP (C1.4), the existing capacity, is greater than zero, the costs in the fields C2 through C9 represent costs to be added to the existing costs for determination of total costs. All costs are expressed in thousand dollars (1000).

NOTE: Fixed cost components for an optimization run (variable CAPDES (PD.4) is greater than zero) should be input for cost items that are not considered a function of installed capacity.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	C2	Card identification characters.
1	JSTATE	+	Two digit code from Table (page 27 of Exhibit 7) indicating the state the project is located. Used to adjust land acquisition, construction and replacement costs.
2	CIO (0)	0	Inlet and outlet costs are automatically calculated.
		+	Cost estimate of inlet and cutlet facilities.
		-	Adjustment factor to be appled to the computer calculated value. A value of -1.23 would increase the value by 23 percent. NOTE: When determining costs for adding capacity to an existing installation (variable ECAP (C1.4) is greater than 0) this value represents the percentage of the original cost of this item to be allocated to the hydropower addition. A value of -0.23 would allocate 23 percent of the original inlet and outlet cost to the addition.
3	CPWH (0)	0	Cost of powerhouse is automatically calculated.
		+	Cost of powerhouse.

FIELD	VARIABLE	VALUE	DESCRIPTION
		-	Similar to explanation for cost of inlet and outlet (Field C2.2).
4	CEMB (0)	0	Cost of embankment is automatically calculated.
		+	Cost of embankment.
		-	Similar to explanation for cost of inlet and outlet (Field C2.2).
5	CSPW (0)	0	Cost of spillway is automatically calculated.
		+	Cost of spillway.
		-	Similar to explanation for cost of inlet and outlet (Field C2.2).
6	CWWY (0)	0	Cost of waterway is automatically calculated.
		+	Cost of waterway.
		-	Similar to explanation for cost of inlet and outlet (Field C2.2).
7	CRC (0)	0	Cost of reservoir clearing is is automatically calculated.
		+	Cost of reservoir clearing.
		-	Similar to explanation for cost of inlet and outlet (Field C2.2).
8	CLA (0)	0	Cost of land acquisition is automatically calculated.
		+	Cost of land acquisition.
		-	Similar to explanation for cost of inlet and outlet (Field C2.2).
9	CMIS (0)	0	No miscellaneous costs are added.
		+	Any additional fixed costs in dollars not provided in other fields of the C2 card.

C2

FIELD	VARIABLE	VALUE	DESCRIPTION
10	COSTR (0)	0	No adjustment factor will be applied to input costs estimates.
		+	Adjustment factor (decimal) to be multiplied times the annual cost (Item 20 in the cost estimate form).

6.3 CF CARD - Cost of Financing the Project Card

The CF card specifies cost information necessary to calculate the repayment of the project costs.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	CF	Card identification characters.
1	CONT (0.25)	0	A contingency factor of .25 (25 percent) will be used.
		+	Contingency factor (decimal) applied to the construction costs. A value of 0.25 indicates a contingency factor of twenty-five percent.
2	RATE (0.06875)	0	An annual discount rate of 0.06875 will be used in the computations.
		+	Annual discount rate (decimal) to be used in the computations.
3	AMOP (100)	0	Amortization period of 100 years will be used in the computations.
		+	Length in years of the amortization period to be used in the computations.
4	PTC (2)	+	Project time of construction in years. Suggested times from the NPD (1979) cost estimating manual are shown below. Addition of a power plant to an existing dam - 2 years. Diversion project or small hydropower and dam project (dam height less than 100 feet) - 4 years. Medium hydropower and dam (project dam height 100 to 250 feet) - 5 years. Large hydropower and dam project (dam height greater than 250 feet) - 6 years.
5	REPL (0.0125)	+	Replacement cost factor.

7 OC CARD - Optimization Criterion Card

The OC card specifies the information necessary to define the objective function used to optimize the installed capacity. Optimum capacity selection will automatically be performed if CAPDES (PD.4) is omitted. If the OC card is omitted output variable 26 (Table 2), annual net benefit, will be maximized.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	OC	Card identification characters.
1	IVAR1 (26)	0	Total annual net benefits ($/year) will be optimized. (both cost and benefit information must be provided on the PB, CB, EB, C1, C2, CF cards).
		+	Two digit numerical code indicating what variable in Table 2 (page 16 of 40 of Exhibit 7) is to be maximized or minimized.
2	IVAR2 (0)	0	Only the variable specified in field OC.1 is to be optimized.
		+	Two digit numerical code indicating the second variable in Table 2 to be combined VAR1.
3	ICOMB (0)		This field specifies what type of combination of VAR1 and VAR2is to be optimized.
		0	Optimize VAR1 only
		1	Optimize the sum of VAR2 and VAR1
		2	Optimize the remainder when VAR2 is subtracted from VAR1.
		3	Optimize product of VAR1 and VAR2.
		4	Optimize ratio of VAR1 and VAR2.

FIELD	VARIABLE	VALUE	DESCRIPTION
4	OPERND (MAX)		This field indicates whether the optimization function is to be maximized or minimized.
		MAX	Select the installed capacity which maximizes the variable.
		MIN	Select the installed capacity which minimizes the variable.

OP

8 OP CARD - Optimization Ordinate Card

The OP card specifies the percent of time exceeded ordinates used in the optimization table. The default percent of time exceeded ordinates of 1,5,10,20,40,60,80,90,95, and 99 are used if the OP is omitted. NOTE: This card is only operational during annual power analyses.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	OP	Card identification characters.
1-10	OP	+	Percent of time exceeded ordinates used in the optimization table.

9 PS CARD - Printout Suppression Card

The PS card enables the user to specify desired output. The complete output will be printed if the PS card is omitted. The user must enter the sum of values to indicate which of the described items are to be suppressed in the printout.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	PS	Card identification characters.
1	PLOTS (0)	0	No plots will be suppressed.
		1	The streamflow-duration plot is suppressed.
		2	The total capacity-duration plot is suppressed.
		4	The existing capacity-duration plot is suppressed.
2	CEFS (0)	0	No cost estimating forms will be suppressed.
		1	The total potential capacity cost estimate form will be suppressed.
		2	The existing capacity cost estimate form will be suppressed.
3	ECHOS (0)	0	The summary of the input variables and program options printed at the beginning of the job will not be suppressed.
		1	The summary of input variables and program options printed at the beginning of the job will be suppressed.
4	CALCS (0)	0	None of the following items will be suppressed.
		1	The tabulated ordinates of the adjusted flow-duration curve will be suppressed.

PS

FIELD	VARIABLE	VALUE	DESCRIPTION
		2	The table summarizing the optimization calculations will be suppressed.
		4	The table summarizing the power potential results will be suppressed.
5	IPRNTS (0)		Seasonal printout indicator
		0	Only final (annualized) information will be printed.
		4095 (or greater)	Print all season's output
		1	Print 1st season's output.
		2	Print 2nd season's output
		4	Print 3rd season's output.
		8	Print 4th season's output.
		16	Print 5th season's output.
		32	Print 6th season's output.
		64	Print 7th season's output.
		128	Print 8th season's output.
		256	Print 9th season's output.
		512	Print 10th season's output.
		1024	Print 11th season's output.
		2048	Print 12th season's output.

PS

FIELD	VARIABLE	VALUE	DESCRIPTION
10	TRACE	0	Suppress all program trace output.
		1	Trace power calculation for exisitng or incremental capacity.
		2	Output existing powerarrays.
		4	Output incremental power arrays.
		8	Output optimization power arrays.
		16	Output fixed power incremental arrays.
		32	Output fixed power arrays.
		64	Output optimization matrix.
		128	Trace optimization function.
		256	Trace QGUESS/SELQ calculations.

EJ

10 EJ CARD - End of Job Card (Required)

This card must be provided at the end of each job. Multiple jobs can be executed by providing subsequent sets of T1 through EJ cards.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	EJ	Card identification characters.

HYDUR

SUMMARY OF INPUT CARDS

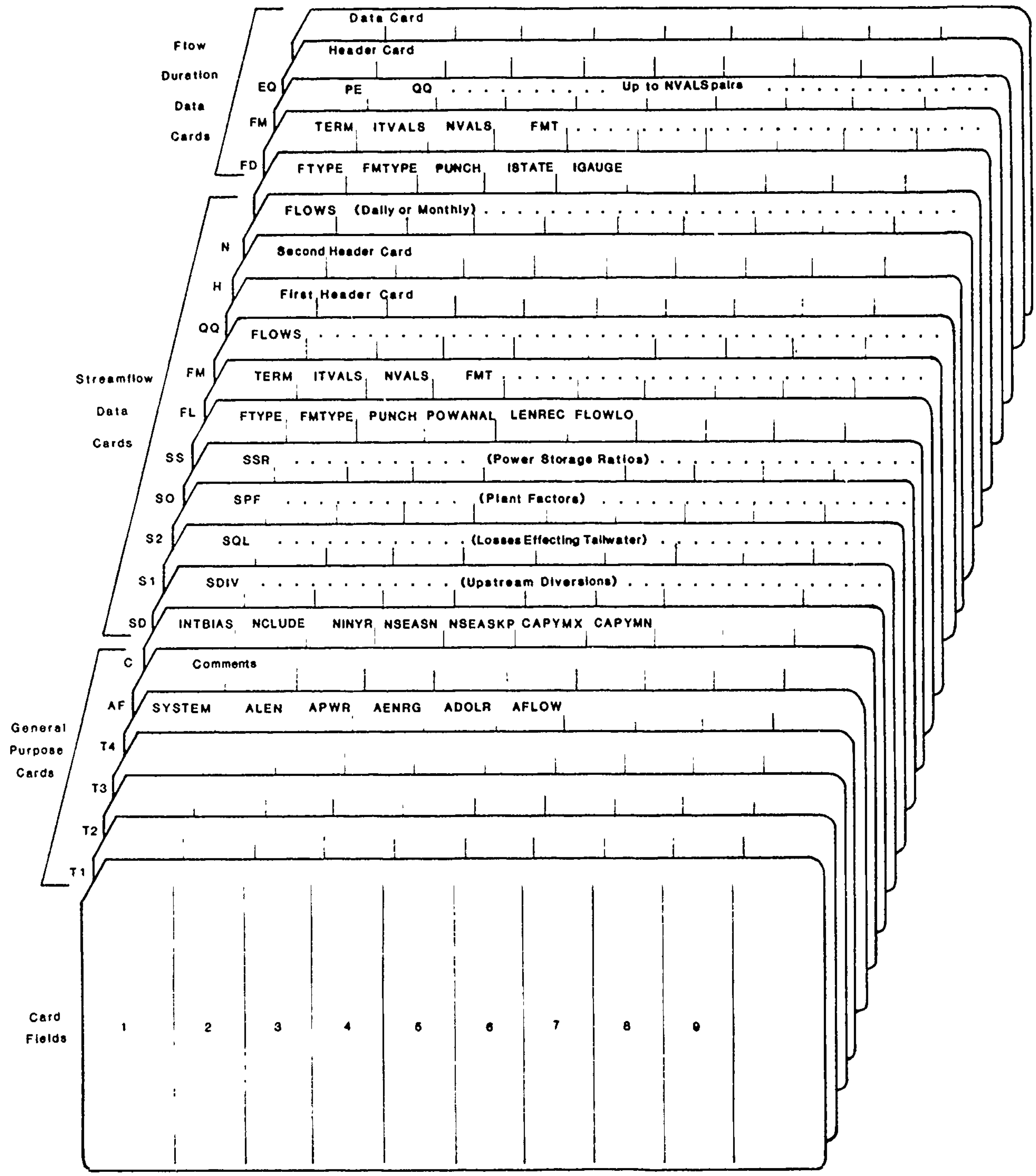


Exhibit 7

HYDUR

SUMMARY OF INPUT CARDS (CONTINUED)

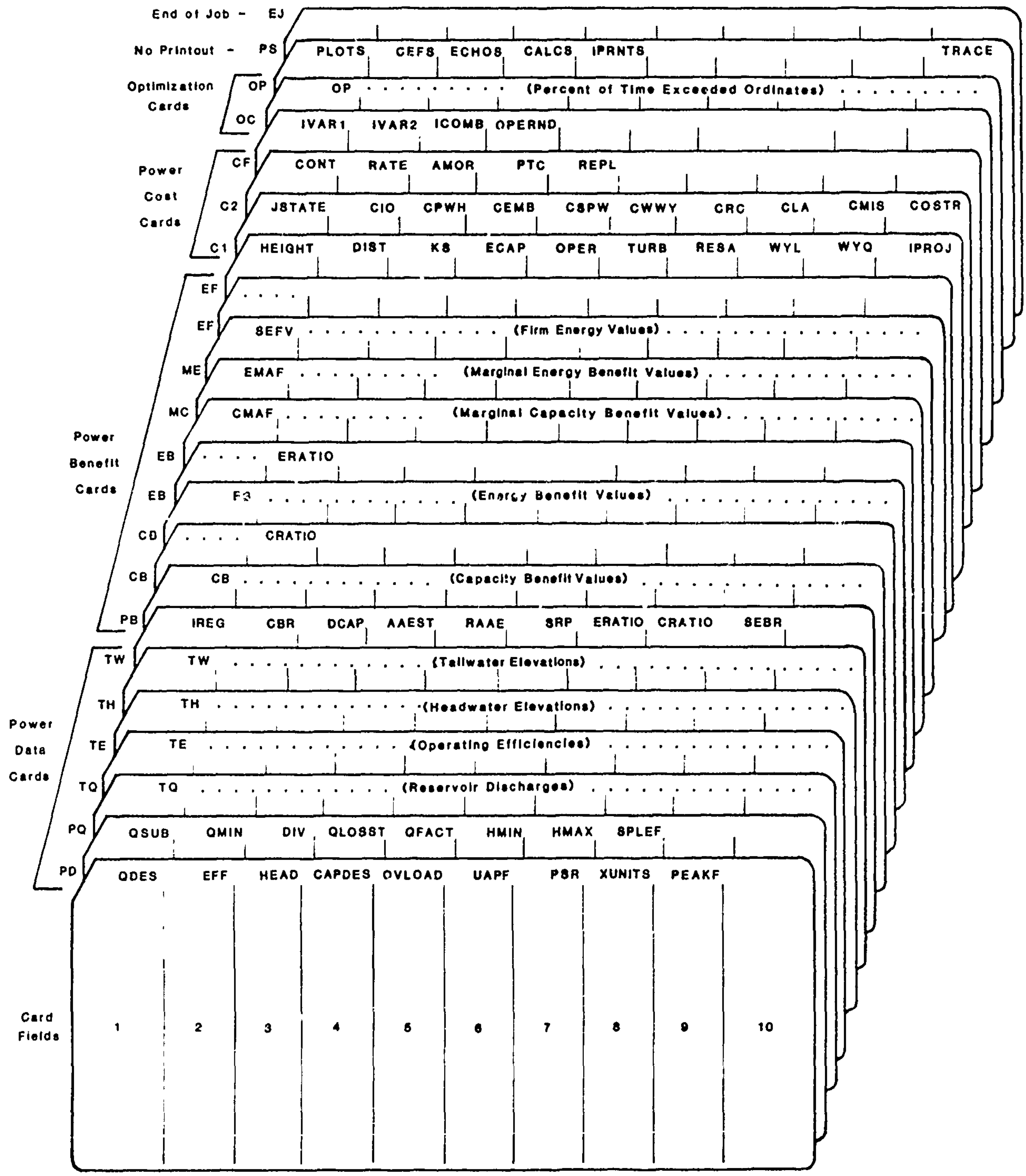


Exhibit 7